

AD-A015 571

ADVANCED DEVELOPMENT, XM-742 SOFT RAG PROJECTILE

K. W. Misevich, et al

Remington Arms Company, Incorporated

Prepared for:

Edgewood Arsenal

May 1975

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE

**Best
Available
Copy**

FINAL REPORT
ADVANCED DEVELOPMENT
XM-742 Soft RAG Projectile

MAY 1975

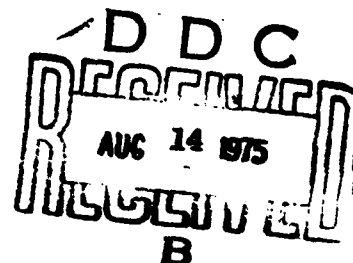
AB 75-2

This work was supported and monitored
by the U.S. Army, Edgewood Arsenal,
Maryland under Contract No. DAAA15-74-C-0221

Prepared by
K.W. Misevich

Work Done By: K.W. Misevich
J.J. Scanlon
C.L. Jackson
M.M. Carriere
J.S. Gardner

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. Department of Commerce
Springfield, VA. 22151



DECLASSIFICATION STATEMENT A

Approved for public release;
Distribution Unlimited

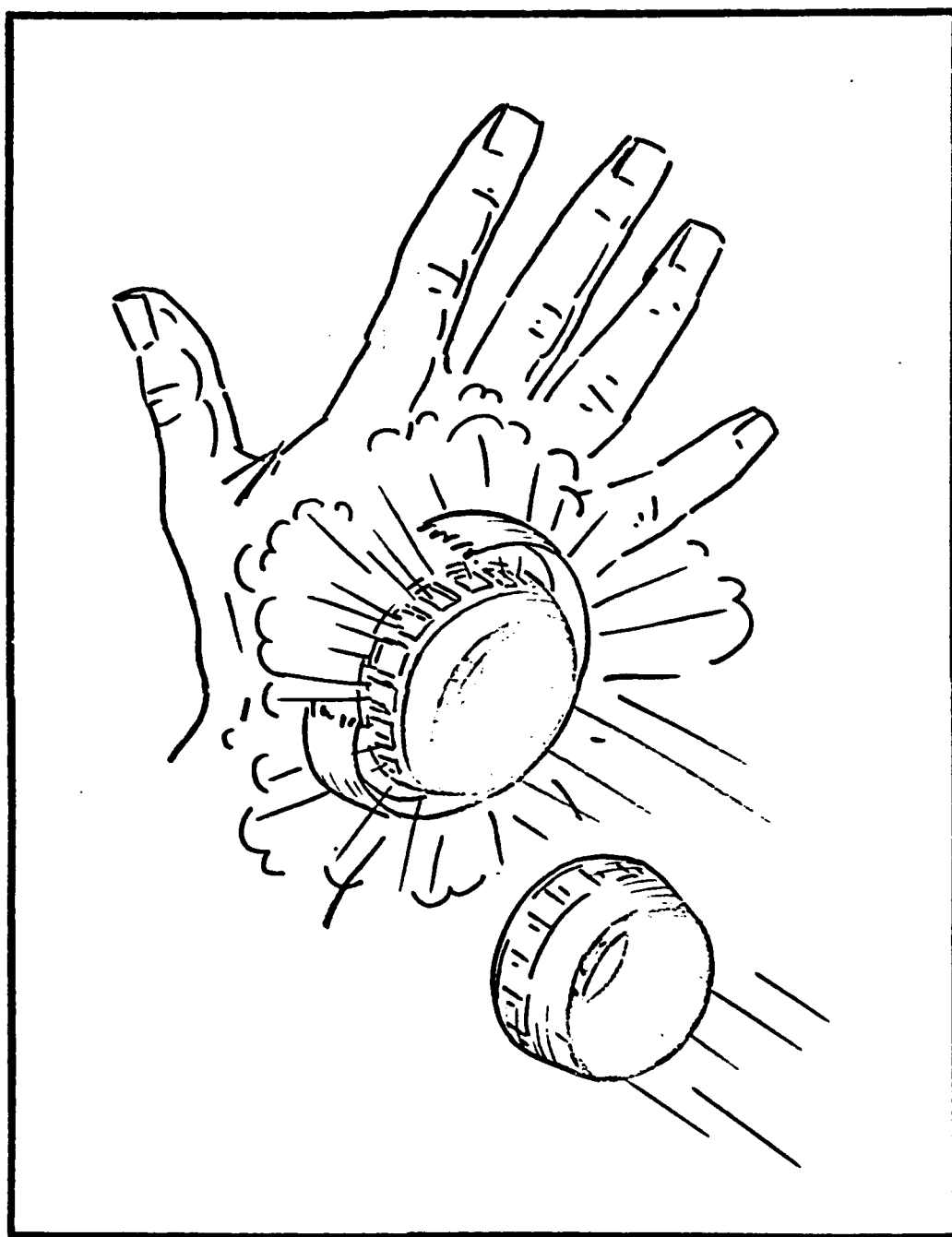


TABLE OF CONTENTS

	<u>PAGE</u>
INTRODUCTION	1
OBJECTIVES	3
SUMMARY	5
PATENT STATEMENT	7
EXPERIMENTAL DETAILS	
● Basic Specifications	9
A. Design Criteria	10
B. Materials	11
C. Payload	13
● Projectile Body	13
A. Mold and Mold Material Requirements	15
B. Mold Making	15
C. Rubber Molding Process	19
D. Body Production	25
● Payload Package	26
A. Mold/Material Requirements	27
B. Package Machine Design	29
C. Process Description	33
D. Package Production	38
E. CS-2 Loading Summary	39
● Breakband	43
A. Banding Material Requirements	45
B. Banding Machine Design	46
C. Banding Process	48
D. Breakband Production	50
● XM-742 Production	54
● XM-742 Testing	57
FUTURE WORK	73
APPENDIX - XM-742 Loading Clip	76

FIGURES

FIGURE NO.

- | | |
|-------|---|
| 1 | XM-742 Program Schedule |
| 2 | SRP #3 Soft RAG Projectile (CRL-2628) |
| 3 | XM-742 Soft RAG Projectile (CRL-2671) |
| 4 | Synthetic Mold Masters (BRL-2676) |
| 5 | Production Mold and Holder (CRL-2672) |
| 6 | Sprue Cutter (SKRL 11-1974-1) |
| 7 | XM-742 Prototype Package Mold (SKRL 5-2474-1) |
| 8 | XM-742 Package Machine Assembly Drawing (B278-17 Sh. 1) |
| 9-20 | Package Machine Details (B278-17 Shs. 11-22) |
| 21 | Breakband Wrapping Process (DRL-2673) |
| 22 | Breakband Tissue Folder (SKRL 5-1074-1) |
| 23 | Tissue Folder Drive Wheels (SKRL 5-1374-5) |
| 24 | Breakband Tissue Impregnator (SKRL 5-2274-1) |
| 25 | Breakband Tissue Guide Roller (SKRL 9-1374-1) |
| 26 | Unit Banding Mandril (SKRL 7-1474-1) |
| 27 | XM-742 Banding Machine Assembly Drawing (B278-17 Sh. 101) |
| 28-29 | Banding Machine Details (B278-17 Sh. 102, 103) |
| 30 | Breakband Cutoff and Slitter (CRL-2677) |
| 31 | Sting RAG Test Matrix |
| 32 | XM-742 Loading Clip (CRL-2648) |

NOTE: Large drawings have been reduced and attached for reference only.

TABLES

	<u>PAGE</u>
TABLE 1 List of XM-742 Projectiles Delivered to Edgewood Arsenal	55
TABLE 2 Summary of Inspection Data for CS-2 and Talc-Filled XM-742 Projectiles	56
TABLE 3 Hot Storage Tensile Tests	67
TABLE 4 Tensile Tests on Breakbands Cured at Various Cycles	68,69

INTRODUCTION

This report covers work carried out under Edgewood Arsenal Contract DAAA15-74-C-0221 on the Advanced Development Phase of a non-hazardous ring airfoil grenade (RAG) projectile. The feasibility of the RAG projectile was proven by Edgewood Arsenal¹ and carried through the Experimental Development phase by Remington Arms Company, Incorporated.²

The Ring Airfoil Grenade (RAG) shape has aerodynamic properties which provide a relatively stable low trajectory flight. When made of a soft material and filled with a riot control agent, it is capable of providing a long-range delivery method that is kinetically non-hazardous. This report describes the work which was carried out at Remington Arms Company, Inc., from May 15, 1974 to February 28, 1975, to develop prototype production equipment.

Prior to this Advanced Development effort, all previous Soft RAG projectiles were made on hand-operated equipment with the fabrication parameters being monitored and recorded so the transition to semi-automatic equipment could be done readily.

In the initial contract³, only fluidized talcum powder was used as a payload simulant. This contract required that the feasibility of fabricating projectiles with the actual riot control agent, CS-2, be established.

¹Donald N. Olson, "A Kinetically Non-Hazardous Ring Airfoil Projectile for Delivering Riot Control Agent," EATM-2200-6, August 1972.

²Kenneth W. Misevich, "Design Study for Soft RAG Projectile," Remington Arms Company, Incorporated, (AB 74-3), Bridgeport, Connecticut. (Work was supported and monitored by the U.S. Army, Edgewood Arsenal, Maryland, under Contract No. DAAA15-73-C-0047.)

³Ibid.

Facilities were constructed and safe operating procedures were determined to do this.

In this report the basic specifications of the projectile are considered first and then the machinery and processes to produce it. Discussion of the machinery is separated according to the three projectile components: 1) the rubber body, 2) the payload package, and 3) the breakband. The history of the XM-742 RAG production is traced through the contract with special emphasis placed on the fabrication of CS-2 loaded projectiles. Finally, a summary of various firing tests and special breakband investigations are considered.

Somewhat independent of the main activity of the contract are the development of a loading clip and extensive tests conducted by Edgewood Arsenal during this period of time. Work done on the loading clip is presented in the Appendix.

OBJECTIVES

The purpose of this contract was to refine the design of the Soft RAG Projectile, Design SRP #3 (now designated XM-742), and to develop prototype production equipment to produce the complete projectiles.

Throughout this contract the Soft RAG projectile program was directed toward these goals:

- The projectile payload seal and performance function must be maintained
 - after normal handling and shipping and at least five foot free drop
 - over the temperature range of 20°F to 130°F
 - at launching velocities of up to 250 ft./sec. and spin rates of 6000 rpm
- The projectile must maintain its designated aerodynamic shape and center of gravity so as to
 - hit an individual at 40 meters and a small group at 60 meters at least 80 percent of the time
 - disseminate at least 95 percent of the payload (Agent CS-2) upon direct and grazing impact on both hard and soft targets and cause no injury to the target personnel (no fuzing mechanism is allowed)
- The projectile materials must be compatible with Agent CS-2 for long term storage of five years from -30°F to 130°F and 5 percent to 90 percent R.H., and they must be non-hazardous to the target personnel.

- The overall production including body fabrication, assembly, filling, sealing, and packaging must be economically acceptable.

SUMMARY

The SRP #3 Soft RAG of the previous experimental development program was optimized until acceptable to Edgewood Arsenal. Body configuration and breakband variations effected major improvements in producibility and soft target dissemination. Prototype production machinery was designed, fabricated, and studied while being used to make over 1300 projectiles for contract delivery, including almost 500 loaded with the CS-2 riot agent. While material properties testing was carried out for process and performance variation, much of the desired firing test program could not be satisfactorily completed. Since the system launcher was being concurrently developed, tests were conducted under constantly changing conditions and the testing schedule was not completed as a final design launcher was not provided.

The XM-742 projectile body was greatly altered from the SRP #3 design. Part of the outer diameter aerodynamic profile was changed to a flat chord to enhance producibility and the rubber material was densified with powdered brass to increase the weight and range. The payload package remained essentially the same except to accommodate the flattened body profile. The breakband was modified by a change in wrap rate and improvement of the quality through small process variations. Conformity and integrity were improved while maintaining the combination of suppleness with low ultimate strain, 1-1/2 - 2 percent, found necessary for good soft target dissemination.

XM-742 projectile bodies were molded in the same transfer press used for the SRP #3. The revised configuration was first incorporated into a

steel mold for initial production, but within four months the synthetic molds described in the proposed process were in operation. Production of large numbers of Soft RAG projectile bodies produced with these epoxy molds showed the feasibility of the multiple mold concept.

The payload package and banding machines were designed, fabricated, and in initial operation two months after the start of the contract. This allowed the final configuration for the XM-742 projectile to be established very early in the program for launcher/projectile coordination. It also permitted long-term evaluation of their operating characteristics to be initiated on schedule.

The package machine combined the proven laboratory fabrication techniques into a continuous, controllable process which is now capable of making over 100 packages per hour.

The banding operation was semi-automated from the hand operation already established. A single wrap of folded 1/4 inch wide tissue is made over a production batch of six projectiles. Wrap rate and speed controls allowed the breakband quality to be markedly improved. Other than wrap rate variation, the drying and crosslinking post-operations were the most important areas of investigation. These procedures along with the addition of crosslinking catalyst permitted the successful reduction of the ultimate strain while maintaining consistent tensile strengths.

The successful culmination of the production machine development phase was reached when projectiles were made with the actual CS-2 riot agent. Although there were a lot of practical problems uncovered, the feasibility of the total production scheme was effectively shown.

PATENT STATEMENT

Under the earlier Experimental Development Phase of this work, improvements were made in the design of the projectile, in a new captive piston sabot launcher, and in a new clip concept to facilitate loading the projectile into the launcher. These developments were reported to the Government on Form DD-882 on April 15, 1974, and Application Serial No. 504,971 entitled "Pay Load Carrying Tubular Projectile" was filed on September 11, 1974, and Application Serial No. 504,972 entitled "Loading Device for a Tubular Projectile" was also filed on September 11, 1974. Confirmatory Licenses for both of these applications were forwarded to the Government on October 22, 1974. Remington elected not to file a patent application on the launcher improvements as noted on the Form DD-882 report and apparently the Government has no further interest in that improvement.

Under the present contract there were some refinements made in certain design parameters of the payload carrying portion of the tubular projectile but none which appear to be patentably distinct from the projectile disclosed and claimed in Application Serial No. 504,971 or in the prior applications resulting from earlier work at Edgewood Arsenal by Abraham Flatau, Donald N. Olson and Miles C. Miller. The Government has royalty-free license rights under these inventions.

Under the present contract a fair amount of work was done in developing methods for molding the rubber-like projectile body, but it is believed that this work consisted mainly in the adaptation of known molding techniques to this particular problem, and it is believed that no patentable inventions were made.

Similarly, work was done in mechanization of the payload packaging concept developed under the previous contract where the payload packages were fabricated one at a time. This work is believed to have simply brought together into one compact continuously operating machine an aggregation of known and previously used techniques and as such does not appear to involve patentable inventions. Further, it may be noted that this machine requires further refinements before satisfactory continuous operation is achieved.

The prototype banding machine was a simple extension of proven laboratory techniques developed for applying the breakbands during the previous contract and again does not appear to have involved patentable invention.

EXPERIMENTAL DETAILS

Since the contract Scope of Work required the Soft RAG projectile project to provide projectiles to meet the tight schedule of the launcher development, the initial activity had to concentrate on achieving workable production machinery in the shortest possible time. A program schedule for the XM-742 was formulated, as shown in Figure 1, to have machinery ready just two months after the inception of the contract.

A knowledge of the design, functioning and fabrication of the previous SRP #3 shown in Figure 2 permitted the program to be pursued with great confidence.

Basic Specifications

The SRP #3 Soft RAG projectile evolved from many design configurations to a projectile which functions as desired except for reliable dissemination against soft targets. Its components - rubber body, payload package and breakband - all were developed using materials generally available with production feasibility being demonstrated on a laboratory scale. One purpose of the contract was to refine the design of the SRP #3 RAG projectile in order to conclude this contractual effort with firm design specifications for the XM-742 projectile.

The first step in this program was a complete review of the SRP #3 design at Edgewood Arsenal on May 7, 1974. The basic elements of the design were accepted, but two modifications were immediately recommended: 1) deepening of the payload cavities to allow a greater agent-carrying capacity, and 2) elimination of the fiberglass insert in the body tail portion and extending the breakband further back toward the tail.

It was also understood that the total body weight might have to be modified to achieve ballistic commonality with the Sting RAG projectile (XM-743). In addition, it was recognized that the quality of the package might need improvement and the breakband wrapping adjusted to enhance dissemination against soft targets while maintaining launching and flight integrity.

Figure 2 shows how the walls separating the payload cavities conform to the outer diameter shape of the ring airfoil grenade as specified by Edgewood Arsenal. Initial study of production improvements pointed to this shape for the walls as a very troublesome aspect of both the body mold fabrication and the payload package vacuum dies because the compound curvature is extremely difficult to machine. In fact, the proposed method of replicating the body molds with synthetic materials would be greatly complicated.

A request was made to Edgewood Arsenal proposing that the diameter profile of the projectile body over the payload cavities be changed to a flat chord and that the overall radial dimensions of the body be increased by 0.040 inch so that the finished RAG projectile maximum diameter would be maintained. The advantages for production far outweighed the only detrimental functional effect of slightly increasing the aerodynamic drag. The request was approved.

A. Design Criteria

The testing and fabrication experience with the SRP #3 indicated that only minor design adjustments would be needed during the course of this work. The important criteria that had to be followed can be stated quite simply:

Body

- The overall shape has to provide the correct aerodynamics.
- The size and shape of the payload cavities might be changed but must easily accept the final package.
- The ballistic weight of the body can be adjusted by densification only if the general processibility and performance are satisfactory.

Package

- The design of the container and cover are strictly dependent on the body cavities into which they are placed.
- The vacuum-formed plastic body must be compatible with the Agent CS-2 and be leak-free.
- The package cover must seal the cavities and yet break open whenever the breakband breaks off during impact, including grazing.

Breakband

- The materials and process for the breakband had been carefully selected to provide strength and suppleness with low ultimate breaking strain over the required environmental conditions.
- Since the breakband is applied as a 1/8-inch wide band, the major design variable is the wrap rate over the length of the projectile.

B. Materials

The materials for the construction of the three SRP #3 projectile components had been selected on the basis of performance, processibility and economic availability. The materials selected are described below:

Body - Du Pont's Nordel® elastomer, an oil extended EPDM rubber formulation, was chosen above many other materials because of its apparent compatibility with the Agent CS-2, good physical properties, processibility, and availability. In this contract a brass filler was added to the Nordel® elastomer to increase specific gravity, and thus, ballistic range. In addition, the brass filler enhanced thermal conductivity which reduced the curing time.

Package - The package body film was selected because of its compatibility with the CS-2 agent and cost. For these reasons, a 5 or 6 mil black polyethylene film was chosen.

Thin aluminum foil was selected as the cover material for the package because of its effectiveness as a seal and of its ability to break readily on impact.

An attempt was made to provide the grey color code for the RAG projectile body as requested by Edgewood Arsenal by coloring the Nordel® elastomer. This approach was terminated since the grey formulations reduced the moldability properties. If ultimately required, the grey color could be applied by painting.

Breakband - Cellulosic tissue wrapped with a water-based binder around the projectile body at various wrap rates per unit length was the optimum material found for this purpose. The tissue selected was Aldex 17 supplied by the Gould Paper Company. The minimum width which could be provided on large rolls was 1/4 inch. The tissue impregnated subsequently with an ethylene vinyl acetate binder, Du Pont Elvace® 1968 commonly used in the textile industry, made it possible for the breakband to successfully pass environmental and performance tests.

Nordel® elastomer is a trademark of the Du Pont Company for a particular elastomer. Elvace® resin is a trademark of the Du Pont Company for a particular resin.

C. Payload

All preliminary developmental work on the RAG projectile had employed a fluidized talcum powder simulant, not as dispersible as CS-2, but satisfactory for observing the payload dissemination characteristics of the projectile. (In this program its use was continued for projectile development work, packaging variations, and package fabrication as required for testing and evaluation to prove the validity of the Soft RAG concept.)

CS-2 is a non-toxic powder but is a very powerful irritant. For this reason a special facility had to be developed to handle the packaging, assembly, banding and final curing of the projectiles. A laboratory with a satisfactory fume hood/scrubber was selected. A safe operating procedure was agreed upon by Edgewood Arsenal and Remington Arms Company safety personnel. The production machinery was designed to be portable and amenable to installation in the special area for the short duration of the CS-2 loading.

The Projectile Body

When rubber was first used as a body material for the RAG projectile, carbon steel compression molds were used. Rubber billets had to be carefully formed and set into the mold. This was adequate for simple designs. However, the SRP #3 design with the payload cavities and walls could not be molded in this way. A transfer press was therefore acquired and a new mold set built. The SRP #3 was molded at a rate of less than 10 per hour, clearly unsatisfactory for the much larger numbers of Soft RAG's which had to be produced.

Since there was some probability that the body design would change during the course of the contract, the cost of multiple injection molds of the

complexity required was prohibitively expensive, and totally inflexible to design changes considering the time and money that was contracted for this program. Therefore, a production concept was developed which employed as its basis a single transfer station with multiple synthetic molds introduced singly for filling and then held closed separately to achieve whatever production rates were required.

A preliminary stainless steel mold had to be made immediately so that initial test requirements could be met until the synthetic molds were developed. As already mentioned, the outer diameter of the projectile was flattened to a chord over the payload cavities, the recess to accommodate the breakband was eliminated, and the overall radial dimensions increased by 0.040 inch to keep the same outer diameter. The XM-742 projectile representing these changes is shown in Figure 3.

The XM-742 preliminary steel mold was composed of three major parts:

- 1) the nose cavity which contained the inner diameter annular entrance gate,
- 2) the tail cavity, and 3) the payload cavity ring. The press on opening separated the nose and tail portions leaving the molded body to be stripped from the removable ring mold. Only a relatively small number of bodies were molded with the steel mold to check the feasibility of the projectile redesign, and provide initial test projectiles.

The steel mold was mounted directly in the transfer press and had to remain empty for almost half of the six-minute molding cycle (3-1/2 minute clamp, 2-1/2 minute strip and load). The synthetic molds, on the other hand, were removed from the press as soon as the rubber was transferred in and was firm enough for handling. The cycle time for three molds was about two and one-half minutes.

A. Mold and Mold Material Requirements

In order to effectively transfer the rubber into a 350°F mold, plunger pressure of about 1200 to 1800 psi is required. This, in turn, necessitated approximately 5 tons clamping force to keep the mold closed. The synthetic molds initially had difficulty in withstanding these conditions. This problem was overcome by reinforcing the molds with aluminum components as shown in Figure 5.

To fabricate the synthetic molds, mold masters were first made out of steel to the projectile dimensions shown in Figure 3. Then molds were made of various synthetic materials - polyimides and epoxy were the first candidates.

The mold masters, shown in Figure 4, were designed to produce parts essentially the same as those produced by the steel ones used for the preliminary feasibility work. Since there was no way to know which material would be used, the design was purposely kept simple with cast/compression molds. The dimensions were set for room temperature steel so it was expected that the final production parts would be larger or smaller depending on the mold expanding to 350°F and the rubber shrinking as it returned to room temperature. However, the airfoil shape of the projectile was always maintained.

B. Mold Making

Initially two types of materials were acquired for producing the replicated molds--polyimides and high-temperature epoxies. After some experimentation, it became obvious that molding polyimides (Kinel[®] 5518 and 5505 supplied by Rhodia Inc., New York) was much too complicated on the time scale established for the program. The material came in a fluffy powder form which required

Kinel[®] plastic is a trademark of Societe des Usines Chimiques Rhone-Poulenc, Paris, France, for a particular plastic.

preforming before it could even be fit into the available space of the molds. Then it required high pressures (1500 to 4500 psi) and temperatures (430° to 500°F) to be formed properly. The mold masters could make the nose and tail portions of the mold but not the payload ring. There was difficulty in easily obtaining more of the material which also happened to be toxic and required special handling. It was, therefore, decided to concentrate on the high-temperature epoxy.

The epoxy used throughout the rest of the program was RP-4032-A HI-HEAT (supplied by REN Plastics, Lansing, Michigan) which can be used up to 400°F. The room temperature physical properties more than satisfied the requirements of the mold pressures, but these decline with increasing temperature. A combination drawing of the final epoxy molds in aluminum holders is shown in Figure 5.

The process developed to fabricate the epoxy molds is described below:

- Clean all mold master parts and three aluminum sleeves, spray lightly with KORAX 1711 release agent (Contour Chemicals, Woburn, MA), wipe excess with tissue and set at room temperature.
- The epoxy resin is previously deaerated by first soaking at 200°F, stirring vigorously to eliminate any settled aluminum powder, and subjecting it to a greater than 25 inch Hg vacuum for about 15 minutes. It is then stored at 125°F until used.
- Mix about 200 grams of epoxy, paint profile surface of tail master on rotating table, pour epoxy on surface of tail master bottom (with pins), pour remainder into profile of tail master now in sleeve. Let set at room temperature for 1-1/2 hours before closing.

- Using remainder of first epoxy batch, impregnate 7-ounce fiber-glass cloth (1 x 12 inches) and wrap around core of nose master mold to reinforce entrance hole.
- Mix about 150 grams epoxy, paint profile surface of nose master on rotating table, insert wrapped core, pour level while on rotating table, set sleeve over mold and pour rest of epoxy. Let set at room temperature for 1-1/2 hours before closing.
- Mix 150 grams epoxy, paint sharp lines on ring master with 1/2-inch screw clearance, insert core and hold with screw, place sleeve over mold, pour in epoxy very slowly while on rotating table until fins on core are covered about 1/8 inch. Let set 1-1/2 hours at room temperature before closing.
- Since each mold takes about 15 minutes the closings will be 15 minutes apart. Once closed flush with the 4.000-inch aluminum sleeves and held for these 15 minutes the mold does not need to be clamped further. They are cured approximately 12 hours before removal.
- Touch-up machining is done to chamfer all outside edges, and to remove about 0.020 inch at 5 degrees from the nose to form the annular entrance gate. Eight #79 holes are drilled in the tail for venting. (Note that the tail bottom has pins properly placed to form holes to accept a simple drilling jig.)
- The basic mold dimensions are then measured and recorded as a check against any process variation.

The molds are put into service by inserting them into the aluminum holding sleeves shown in Figure 5, clamped in a 350°F platen press for about an hour and then sprayed with silicone before molding starts. It was found that the initial

clamping was important to produce a final seating of all parts.

The final dimensions of the epoxy molds are dependent on the initial mold master temperature, the epoxy temperature and the cure temperature. It was found that high temperature curing could not be controlled the same for each of the three mold parts and dimensions that started the same in the masters would vary between the nose, tail and ring. This is the main reason for using room temperature curing. The 125°F resin temperature was selected to enhance mixing and pouring without initiating a fast cure as an initial 150°F could do. The resin at 125°F cools down to the mold master temperature without setting off a fast exothermic reaction in the epoxy.

When the process was followed diligently, the mold dimensions from set to set were within about plus or minus 0.002 inch on the fixed master dimensions. When one mold sleeve was used, the outer diameters also were held this well. Even though the aluminum sleeves were not machined to the same tolerances, all of the important mold dimensions are held internally on the masters so there is no problem in alignment and mating.

Although these epoxy molds have served the purpose for which intended, the handling during disassembly and body stripping takes its toll in cracked parts. The molds were replaced during the molding production on the average of once every two weeks.

The future of multiple synthetic molds in larger production schedules will have to be determined by the selected molding process and the capitalization acceptable. If multiple steel molds are financially acceptable, it

would be more practical. Investment casting in either steel or aluminum may in the long run pay for itself. Certainly, non-metal synthetic molds still can be considered but their lower thermal conductivity and physical properties at 350°F must be balanced against the low cost and versatility.

C. Rubber Molding Process

Utilizing a five ton transfer press, a hot platen hydraulic press and three mold sets, the basic molding cycle was as follows:

- Transfer press open, insert about 550 grain billet (approximately 1/2 inch x 1-1/8 inch x 4 inches) into plunger pot in top press platen.
- Set in hot mold set, close press, actuate transfer plunger.
Plunger starts 2-1/4 minute press cycle.
- When press opens, remove mold and set aside. Insert another hot mold immediately to keep the transfer press in operation (about 2-1/2 minute turn around).
- Remove previous mold from hydraulic press and set aside. Put mold just out of transfer press into hydraulic press and clamp five tons force.
- When the next mold is done in transfer press, the clamped mold is removed, split open on a wedge separator and the body is removed from the ring portion of the mold with pliers.
- The molded body is set aside in a hood to cool down and the mold is sprayed with silicone release as needed, reassembled, and set in the platen of the transfer press to stay hot until ready for the next filling.

A typical mold that starts in the transfer press is loaded within one minute, held for a total of 2-1/4 minutes and then removed. It stands about 15 to 30 seconds outside a press and is then clamped for another 2-1/4 minutes in the hydraulic press. The body is removed and the mold returned to the transfer press to maintain temperature. The three-mold sequence is: First is in the transfer press, the second is in the hydraulic press while the projectile is stripped from the third.

In practice there were two people involved in the molding process so that billets could be prepared and the finished projectiles inspected and deflashed around the payload cavity parting lines as needed. After cooling, a batch of molded bodies were removed to another area to have the web of the sprue cut out of the inner diameter of the projectile. The cutter is shown in Figure 6. Since the annular gate was 0.015 to 0.020 inch thick, the sprue was strongly attached to the body. Experience showed that the web had to be stretched before cutting in order to leave an acceptably small irregularity at the inner minimum diameter of the projectile body.

When the mating edges of the mold parts are new and sharp, any flashing on the outside and sprue cutting on the inside can be eliminated very cleanly. However, the epoxy erodes in time, is damaged during handling, and eventually produces unacceptable irregularities on the rubber body. These could be ground off but it is a time-consuming operation at least under laboratory conditions. Hardened steel molds would presumably eliminate this problem, if marring of the sharp edges is prevented. There is no way of continually sharpening the mold edges without eventually changing the projectile dimensions.

The quality of the final projectile bodies very much depends on the process parameters. They are now covered one at a time.

- Rubber Billets - The material used in the final stages of production is the same Nordel® elastomer formulation as used for the SRP #3 but filled with 30 percent by weight of brass powder (325 mesh). This was simply a non-toxic, non-abrasive densifier to bring up the ballistic weight of the final projectile. This material, Du Pont Fairprene® DS 2902 elastomer, is supplied in slabs 1/2 inch to 3/4 inch thick. It is subsequently sized with a paper shear to the usable 1-1/8 inch x 4 inches billet of about 550 grains, about 100 grains over the weight of the finished projectile body to account for the sprue and to maintain the filling pressure during molding.

The material, when freshly received, processes very easily at lower plunger pressures of 1200 to 1300 psi. As with all elastomers this material ages, especially at warmer temperatures, and eventually cannot be processed. Sometimes the end of the batch is preheated on the transfer press 2 to 5 minutes to aid in filling the mold. This is touchy because too much preheating will quickly start the cure and again make it unusable.

- Transfer Press Temperature - The rubber compound processes best when the molds are at about 350°F. Going even 10 or 15 degrees higher causes noticeable overheating and fuming. It was not specifically checked to see how much property degradation would occur. The press platens are set for 375°F to keep the molds near the correct 350°F. The hydraulic clamping press is simply set at 350°F.

The molds must be soaked at 350°F before molding starts, and they are out of the press for such a short time during the cycle that the temperature is maintained.

Fairprene® elastomer is a trademark of the Du Pont Company for a particular elastomer.

- Transfer Press Clamping Pressure - The clamping force must always be sufficient to hold the mold closed under the internal pressure of the rubber. It was set at slightly under five tons.

As mentioned already, the epoxy molds first make contact and are compressed about 1/16 inch before the aluminum sleeves take up the rest of the load. This keeps the stress of the molds acceptable yet still helps keep the rubber from seeping into the mating surfaces to produce flashing. A clean well-seated mold will be practically flashless. But the accumulated length of the three mold parts are occasionally on the small side so shims are added (.005 to .020 inch maximum) between the nose and top aluminum holder.

- Transfer Press Plunger Pressure - The particular compound used for the projectiles has very good flow characteristics as it is heated up. The main function of the transfer pressure of 1200 to 1600 psi is to force the cool material into the 1/4-inch diameter hole in the top aluminum mold holder for heating and then into the annular gate in the nose section of the mold. If the pressure is lower than 1200 psi, the filling time will go over one minute and some material will have already cured to the point where it will not flow well inside the mold. This, of course, will produce air bubbles.

When operating properly, the transfer plunger starts slowly and then after 30 to 45 seconds surges the rest of the material into the mold and out the vents in the bottom of the tail portion. If extra billet material is used, it will mostly be forced right through the mold and out the vents. The transfer pressure was, therefore, adjusted to fill the mold properly for the gate and vent sizes.

If the vents were plugged, then a higher pressure was present inside the mold producing a heavier body weight, and increased size.

- Entrance Gating - The size of the entrance from the plunger pot to the gate in the mold was selected by experimentation starting with 1/16 inch and increasing to 1/4 inch which just filled the mold well. Since the aluminum-filled epoxy is not as good a conductor as pure metal, this entrance hole serves the purpose of heating up the rubber to near 350°F as it enters. Without this preheating, the mold time is more than seven minutes in epoxy molds.

The separation between the nose and tail section forms a uniform annular gate about 0.015 to 0.020 inch thick. It can be narrowed by shimming the nose to cause more outer diameter compression, but this was not usually done since adequate entrance is required for good mold filling.

The complex internal shape of the mold prohibits the use of discrete runners as gates because excessive air entrapment would develop. Nine such runners were milled into a few molds in order to eliminate the need for a special sprue cutter. Air bubbles, however, became common and flashing eventually started to develop on the inner minimum diameter. This could not be removed with the laboratory equipment available.

- Venting - In all of the steel molds there was natural venting at the tip of the nose and tail because these parts were each made in two pieces. The mating surfaces between the ring, and the nose and tail also could be vented slightly, but they normally should be kept very tight to eliminate flashing. The epoxy molds required additional

venting to be added by drilling eight #79 drill holes at the tip of the tail. These are large enough to have rubber forced out each time the mold is filled. Unless they became clogged, this amount of venting was more than adequate for the process.

Because the mold is taken out of the transfer press to the clamping press it is "bumped". That is, after the 2-1/4 minute transfer press cycle is completed, the mold opens slightly so trapped air can escape before it is reclamped. This resulted in fewer air bubbles than a longer completely clamped cycle in the transfer press.

- Mold Cleanliness - The introduction of brass powder to densify the material did introduce one problem. The powder, in time, starts to build up on the mold surfaces producing a very dull finish on the body part and occasional air entrapment bubbles. Eventually, no amount of silicone release agent is effective and the molds must be removed, scraped clean and repolished. It is not a big problem, but one that must be considered in a production situation.

The brass also eventually clogs the vent holes in the tail so they must be redrilled during the clean-up procedure.

- Part Removal and Clean-up - The only way the body can be removed from the mold is to first pull away the nose and tail and then strip the body into the hole in the payload ring.

The annular gate must be at least .010 inch thick or else the sprue may tear during disassembly. A clean sprue cut is thus prevented.

The only flash removal required is on each side of the payload cavities when the molds do not seat properly or get dirty. All removal was done by hand with scissors during this contract.

The rubber molding process is just like any other. The mold dimensions are set repeatably and the processing conditions held as constant as possible to yield the same part consistently. When this is done, the body weight and dimensions are easily held to within plus or minus one percent.

D. Body Production

During the course of this program, rubber bodies were molded for the Soft RAG directly from the unaltered epoxy molds. Some molds were used for over 1000 projectiles but were then replaced because they were battered from manual handling during disassembly and body stripping. The general mode of failure in the molds was in the payload ring. The reference lip on each side was constantly stressed during the disassembly and a crack would eventually start. Unless more than one-third of this flange would break away completely, there was no difference in the molded part since it is just a concentricity reference.

Variations in body weight and diameter occurred among mold sets because of small differences in the compression forces and venting condition during filling. A given mold set would produce bodies well within plus or minus one percent, but the range of all molds was about three percent. This meant that the body weight for the Soft RAG was nominally 30.5 grams with variation of plus or minus one gram possible in practice. The body weight could be adjusted for a given mold by either shimming the nose to affect the gate thickness and body length by increasing the mold compression, or by shaving some material off the inside of the cavity ring where it really did not matter.

A more coordinated large scale production effort certainly will be capable of providing projectile bodies well within the required tolerances.

Only a careful study of the economics can tell whether separate-press transfer molding, multiple mold transfer molding or injection molding will be best for the long-term production needs.

The Payload Package

The primary function of the Soft RAG projectile is to deliver a payload of CS-2 agent at the target. The agent must not leak out during handling or launching. Previous work with the SRP #3 showed that the best way of introducing the agent into the projectile was to seal it first in its own package. For this reason, the package body was vacuum formed from plastic, filled with agent, and then covered and sealed with aluminum foil. The best plastic for this purpose was found to be polyethylene as it can be vacuum formed and is known to be compatible with CS-2. Aluminum foil was chosen because of its general availability, sealing capability and controlled weakness as it required for dissemination of the agent.

The payload package as shown in Figure 2 for the SRP #3 was first made in a single 18-cavity mold taking about five minutes per package. This included heating the polyethylene film for about 1-1/2 minutes, hand filling the cavities with fluidized talcum powder, an agent simulator, and then heat sealing the cover to the package body. Because this foil was not available initially, tissue was used for the cover. It did not prevent leakage but was adequate for handling and assembly of test projectiles.

Production of 2000 payload packages on a large scale required that automatic equipment be employed to form, fill, seal and cut on a batch or continuous basis. Various packaging machines were screened during the SRP #3 program, and it was decided that the continuous process had the best chance of succeeding.

A. Mold/Material Requirements

The SRP #3 package was made to form fit the outer diameter curvature of the projectile body. While the eighteen cavities were laid out straight in a single mold, a transverse curvature was required to conform to the aerodynamic shape and little cuts had to be made between cavities to allow the package to be assembled without wrinkling on each side. (This occurs because the package is made flat and then wrapped around the projectile. The package sides are at a smaller diameter than the center, and therefore, require a smaller circumference.)

As was stated in the Projectile Body section, the redesign of the outer profile of the projectile into a flat chord over the payload cavities (Figure 3) simplified the mold fabrication for the projectile. Likewise, this flat greatly simplified the package machine. But since the XM-742 package had to be 25 percent deeper than the SRP #3 (i.e. .250 inch instead of .200 inch) a single prototype mold had to be fabricated to prove the feasibility of this requirement before machine construction could begin. The prototype mold is shown in Figure 7.

The package materials were dictated by the functions required: compatibility with CS-2, non-cutting suppleness, effective seal, and a weak cover for dissemination. Experience with the SRP #3 package showed that the polyethylene film had to be at least four mils thick to be drawn into the mold cavities without popping. To accomplish this with the deeper XM-742 cavities, it was considered that a film thickness of 5 to 6 mils

would be required. Further, the best way to enhance heat absorption during the preheating was to use a black carbon-filled film. Anticipating the machine requirements, nominal 6 mil black polyethylene film rolls (2 inches x 1000 feet wound on 3-inch diameter cores) were ordered from Poli-Plastics Products, Inc.*, Oakland, New Jersey.

The cover material chosen was a metal foil since the package required sealing, yet it had to be broken easily if the projectile breakband came off on impact. Regular 0.0007 to .001-inch aluminum foil was tried on the SRP #3 package and was found to provide a satisfactory seal. However, this gauge was much too strong. Two lighter gauges (.00025 inch and .0005 inch 1235-0 alum.) were, therefore, procured from Reynolds Aluminum Company, Richmond, Virginia, in one inch wide rolls. Since these light gauges cannot be primed at the factory for better heat sealing, the material was received in the uncoated state. Shellac primers thinned by Reynolds were also provided in the event it was necessary to prime the foil on the machine. There was not time to enhance the seal by this means.

*0.0053 inch low density polyethylene - DSGA-0585 Union Carbide, 5% carbon, 0.1 melt index, 0.92 density, 103°C melting point.

B. Package Machine Design

The concept for the payload package machine was derived basically from the package fabricating techniques developed for the SRP #3 package. However, instead of fabricating a package one at a time, it was designed to produce them on a continuous basis. The continuous process was accomplished by using a single rotating mold wheel with speed control and a sliding vacuum manifold communicating with the cavities. To form packages, polyethylene film is fed onto the wheel which is then heated and drawn into the cavities by the vacuum present for the length of the manifold plenum. The formed cavities are then passed under a loading hopper and filled with the payload. The aluminum foil is introduced and immediately heat sealed to the film by a hot roller. Finally, the package is trimmed to width. The packages are cut to length by hand as they come off the machine. To insure good dissemination of the payload, the packages are secured to the projectile bodies by rubber paper cement which is applied to the projectile cavities prior to assembly.

Once the operation characteristics of the machine were established, the Du Pont Engineering Research and Development group at Remington Arms detail designed and fabricated the continuous forming packaging machine. A full-scale assembly drawing is shown in Figure 8 with detail parts given in Figures 9 to 20. The components of the machine are described below:

- Frame - Since loading of the agent was to be gravity fed, the machine had to be built vertically. To keep the agent out of the drive mechanism the motor and clutch are situated behind the mounting plate, and all power and feed lines also enter from the back. The size of the machine was limited during this program as it had to fit into a 3 x 6 foot exhaust hood where the CS-2 agent had to be loaded.

- **Mold Wheel Drive Mechanism** - The speed of the packaging mold wheel was regulated with a 1/20 hp electric motor with a speed range of 0.06 to 2 rpm, controlled by transistored SCR speed control and coupled to the mold wheel shaft by an electric clutch. This was set up to maintain a designated motor speed and still be able to disengage the wheel from the drive mechanism for hand manipulation and wheel positioning.

- **Mold Wheel** - The package-forming wheel as shown in Figure 19 is about 10 inches in diameter to accommodate 54 cavities shaped and spaced exactly like the prototype mold of Figure 7. Since some problems were anticipated in start and stop activities only three groups of eighteen cavities were put into the stainless steel wheel. The gap in between allowed a stopping point for the loader without filling any cavities. The mold surface was raised about 3/32 inch to exactly define a reference surface for cutting the package to the correct width. On each side of the mold surface grooves were placed to accept hold-down belts for the polyethylene film which enters from beneath the wheel.

The vacuum is introduced into the cavities through two 0.012 inch diameter holes in the bottom of each cavity communicating with 1/8 inch holes to the back of the wheel.

- **Vacuum Manifold** - The mold cavities have a continuous vacuum applied from immediately after film heating, through loading, and heat sealing, until the package is cut to width and is ready to come off the mold wheel. This is provided by a sliding vacuum manifold shown in Figure 11 which communicates with the 1/8 inch holes on the back of the mold wheel for the necessary angular travel.

- Film Hold, Feed and Hold Down - Room is provided for the rolls of polyethylene film below the mold wheel where it is tensioned by adjustable friction pads. In order to get it onto the wheel a guide is placed near the point where the film goes underneath the hold-down belts. The hold-down belts are garter springs which keep the film from moving sideways before the cavities are vacuum formed, and even during the vacuum drawing so a more uniform package is produced.
- Film Heater - The main requirement of this heater is to soften the film sufficiently to allow a smooth vacuum draw without popping it. This requires a uniform red hot resistance heater which heats the film for about 2-1/2 inches. The heaters were procured from the Hartford Element Company, Newport, New Hampshire, as a special mounting of 1/16 inch Ni-chrome ribbon wrapped back and forth 10 times to have a heating area of 1-1/2 inches wide by 2-1/2 inches long. These become red hot with less than 30 volts ac. Modification of the heater mounting will be discussed in the process description.

(See Figure 17)
- Powder Loader - Experiments with the prototype package mold and various filling techniques showed that direct contact with a sliding hopper was the cleanest and most efficient way of filling the cavities. Cleanliness is especially important since the CS-2 agent is a very potent irritant and is very easily blown around. The loader is shown in Figure 10. It was designed to accommodate a loaded polyethylene bottle from the top and to allow the powder to fall directly into contact with the cavities, four at a time. Just before the filled cavities move out from under

the loader, the powder is somewhat compressed into the cavity by a 45 degree exit angle. Modest vibration of the complete loader is required to keep the powder flowing down and to densify it.

The loading takes place before the maximum wheel height so the package can be sealed before any powder can spill out.

- Cover Holder and Feed - The aluminum foil is held on a shaft on the upper right side of the machine, originally with provision for frictional tensioning, but later as free running as possible. The foil is directed to the molding wheel over a guide and simply is pulled through the wheel operation by being heat sealed to the package. If the package machine is to be run in a high air velocity of a hood, the exposed foil probably will have to be shielded to prevent fluttering that can wrinkle and tear it.
- Heat Seal Wheel - The packages were sealed by utilizing a rolling wheel to produce a continuous line seal. This part of the machine was least known and was the largest possible problem area. It was not known whether polyethylene and aluminum would seal well without applying a primer to the foil so room was left in the foil feed-in area for primer application, if necessary.

The wheel was designed with a central heater covered by bronze bushing acting as the hot bearing. It rode directly on the aluminum foil, with free self-alignment, and turned simply by its contact with the package. This proved unsatisfactory. It was determined that the heat seal wheel should be positively driven in synchronization with the mold wheel. The final heat sealer is shown in Figure 13 and will be discussed in the process description.

- Width Cutter - To enhance uniform breakband application and final aerodynamic shape, the width of the package must be held quite closely, plus or minus .005 inch. Since the width could be cut outside the machine with a hand-cutting jig, this was the last item on the machine to be designed and built. The best way of cutting was not known. Fixed cutting blades were first tried but they dulled quickly. Eventually the cutoff evolved to that shown in Figure 20, adequate for a while but still not quite right, as will be discussed later.

Other items necessary for machine operation were a Variac for the film heater, air vibrator for the loading hopper, a controllable vacuum source and a temperature controller for the heat seal wheel. The vibrator and temperature controller are called out on the machine drawings, along with other purchased parts.

C. Process Description

The operation of the package machine calls for the monitoring of four separate functions: 1) cavity formation, 2) filling, 3) heat sealing, and, 4) cutoff. When all are adjusted properly, the machine will produce packages at the rate of 2 to 3 per minute, depending on the mold wheel speed.

1. Cavity Formation

The formation of a smooth, well-shaped package without leaks to the vacuum is essential to a good continuous operation. With the loader blocked by a thin stainless steel shim placed between it and the mold wheel, and the heat seal wheel held off the mold wheel, the process start-up can begin. The mold wheel is started at a setting of about

45 to 50 percent (< 1 RPM), the vacuum is turned on but prevented from reaching the wheel by a pin valve and finally the film heater is turned on to a dull red setting. The polyethylene is then fed onto the wheel and threaded under the loader until it eventually exits the machine at the cutoff. It takes a few minutes before the heater stabilizes and the vacuum can gradually be turned on just to the full draw condition. Once this is done the cavity formation will continue with no problem. However, the mold wheel builds up heat in about an hour at room temperature and the package does not cool sufficiently before sliding under the loader. This will cause scuffing of the film and shut down.

If the film is heated uniformly and thoroughly, the cavities are drawn in very quickly. The heater straddles the position where the vacuum manifold starts and is set closer to the film at the bottom. As shown in Figure 17, enhancement of uniform heating is achieved with small heat distribution rods and aluminum reflectors. Without these, the film heats up more in the middle and bulges. This causes a crease line to run along the package center.

If the package film is popped or perforated in any way during the operation, the payload powder will be drawn into the mold cavity and eventually will clog the vacuum holes. They can be cleaned somewhat during the operation, but too much will cause a shutdown and require a thorough cleaning. Future redesign of the package machine must be done to insure that the cavities are always well formed and that they never break through. This certainly can be done with:

- improved heating uniformity
- regulated vacuum source
- controlled mold wheel temperature
- periodic treatment of mold wheel with mold release agent, e.g. silicone.

2. Heat Seal

Once the packages are forming well, the aluminum foil can be threaded under the heat seal wheel and the wheel dropped down to put the cover on the package. Initially, it was not known just what kind of a sealing wheel would work best so a design was conceived with a fine 0.010 inch diamond knurl extending to within 1/32 inch of each side of the package where a very slight taper would feather out the edges of the package for better conformity to the projectile. This worked adequately until melted polyethylene built up due to occasional foil breaks at the edge.

The main problem with the heat seal wheel is that it runs on the foil/PE film only by friction. Too much heat or pressure creates a melt layer which can scuff and cause trouble if the foil breaks across the package. The tapered heat seal wheel was finally replaced by a coarser 0.020 inch diamond knurl with no taper as shown in Figure 13.

The sealer is then held down on the foil/film by spring tension adjustment, set at 400°P and adjusted for uniform bearing by set screws in the holder. If the sealer was positively driven, much more pressure could be imposed with a better seal possible. As it is, this sealer produces a good "peel seal", but one which can be broken to cause slight leaks, if the package is stretched by bad cutoff or in removal from the machine.

Whereas a residue of talcum powder from the loader tends to diminish the heat seal, it was found that the CS-2 melts between the polyethylene and aluminum foil. The whole operation can possibly be cleaned up by extending the seal to a greater width so all loader residue is melted and contained by the seal.

The heat seal can be improved by:

- extending the 0.020 inch diamond knurl to the full one-inch foil width
- positively driving the sealer in synchronization with the mold wheel
- possibly incorporating a shellac primer into the foil feed system.

3. Filling

When the package is being well formed and sealed, the cavities can be exposed to the hopper by removing the shim or opening the gate on top, if the bottom of the hopper is empty. The air vibrator is then turned on with about 5 psi air supply pressure and the cavities began to fill nicely. The loader must bear uniformly on the package or else there is a tendency to leave a trail or residue on one side or the other. Scraping of the filler over the major central section of the package is always quite good, if the vibration is not excessive.

During initial debugging it was found that the powder was not being well packed into the cavities. A plug was, therefore, pressed into the hopper to produce a 45 degree exit angle. This helped compress the powder as it is scraped level.

Until field testing experience is acquired with the CS-2 agent, there is really no way to ascertain whether the packages do in fact have enough payload (about 2 to 3 grams at present). The sliding loader does work well but could be modified as described below to enhance convenience in operation.

- Reduce the volume of powder that needs to be loaded after the gate is shut (In practice the placement of the shim under the loader worked but sometimes was the cause of spillage when introduced.)
- Widen the mold wheel surface so that there is more bearing surface.
- Provide definitive suspension and bearing adjustment.

4. Cutoff

A clean width cutoff is necessary for the package to fit the projectile nicely. It also removes the excess polyethylene while the package is still under a vacuum hold-down and thus eliminates stresses in the heat seal which can cause leakage. However, the complete assembly can be taken off the machine, cut and trimmed by hand jigs if necessary. This was the practice at the end of the contract production since the cutoff quality began to deteriorate.

There is no question that a rotary cutoff wheel is required. The design shown in Figure 20 worked very well for quite a while until the hardened cutters started chewing up the side of the stainless steel mold wheel. Little threads of uncut material required hand separation of the package from the edge trimmings and this caused leaks.

Since the cutting wheels ran against the raised portion of the mold wheel under pressure, one blade would eventually run flush with the edge whereas the other would carry the whole cutting interference angle and start removing material from the mold wheel. This does not mean that future mold wheels would also have to be hardened. In fact, only the cutter mounting needs revision. If the cutters are separately adjustable for pressure and cutting interference the edges should be self-sharpening, and trim the packages very cleanly. If the mold wheel surface is widened as suggested previously for other reasons, it is possible that simple pressure cuts right against the surface would sever the edges just as well. At any rate, the cutoff is a matter of careful redesign and precision fabrication.

D. Package Production

The package machine was assembled and in start-up operation just two months after the contract was initiated. Over 1000 packages including about 500 loaded with CS-2 were fabricated. Initially, there was difficulty in forming the package cavities properly without popping the film or leaving a crease from non-uniform film heating. But modification to the heater and vacuum controls have nearly eliminated these problems. The only fundamental redesign which would greatly help the continuous uniformity of the cavity formation is on the mold wheel. Instead of separating the mold cavities into the three sets of eighteen to form single projectile packages, it would be much better to have a non-interrupted set of cavities. With the present mold wheel the first and last cavity of each package string are difficult to form because of asymmetrical film heating and drawing. With a controlled

mold wheel temperature and a very lean misting of release agent on the mold wheel as it turns there is no reason that excellent packages could not be formed indefinitely. When this is achieved, the whole problem of powder clogging the vacuum system would be eliminated.

Throughout the contract, the package machine was operated for only short periods of time. The talcum powder and CS-2 were fed from polyethylene jars, one container filling about 50 packages. If talc sifted out along the loader because of bad leveling and bearing on the wheel, the excess was periodically vacuumed up. The scrap and side cuttings were simply run into waste baskets. What became routine laboratory production was quite a different matter when the CS-2 was loaded.

E. CS-2 Loading Summary

In mid-December 1974, the payload package machine was moved from a general laboratory area into an isolated laboratory and placed in a high velocity hood, with a linear air velocity of over 800 fpm. This hood in turn was enclosed with a wooden cage and sealed with polyethylene construction film. The hood area is 3 feet deep by 6 feet long.

The general area, hood scrubber, protective clothing and emergency safety equipment were inspected and approved by both Edgewood Arsenal and Remington Arms Company safety personnel. The package machine was run with talc first so that the exact operating procedures could be refined and then converted to handle the CS-2.

Packages could be made at the rate of about 100 per hour, but there were some spillage instances, leaking packages and other problems with the

heat seal that resulted in periodic shutdowns. About every two hours, ten pounds of "Cold Water All" were added to the scrubber sump to decontaminate it before releasing to the sewage system.

As long as the hood air velocity was maintained, there was no problem in handling the agent even without gas masks provided all contaminated materials were kept inside the hood. But experience showed that a production area needs to be designed very carefully with all important controls and moving parts well sealed, a place provided for everything (including cutoff scrap) and much more space to move around. In short, provision must be made for every manipulation, adjustment, cleanup, and maintenance. If this is done, there will be no problem in producing CS-2 packages in large quantities.

This makeshift operation was barely capable of getting out the required number of packages because of fouling of the package machine. A number of improvements were made during this short run of CS-2 loading, but others are still needed. These are described below:

- Overall machine operation would be greatly enhanced if the vacuum formation of the package film was made more foolproof. That is, popped film, wrinkles and other irregularities must be eliminated completely. The film heater must be redesigned slightly and most important, the forming wheel should be a continuous series of payload cavities instead of groups of 18 as it is now. Most bad packages were caused by either the first or last cavity since there is an obvious asymmetry in the film heating at these points. The forming wheel temperature should be controlled and possibly some silicone release constantly applied as a very lean mist.

- The CS-2 agent can be removed readily from surfaces by blowing it into the hood air flow. The vibrator worked very well with only a few instances of unfilled cavities. However, there is some residue around the cavities which could be vacuumed in the next generation equipment or the film and heat seal wheel widened. The heat sealer simply melts any residue in the seal region and seems to contain it. In fact, a slight dusting of the agent may even aid as a bonding medium but this must be evaluated when further sealing experiments are done.

The CS-2 agent has one other troublesome property: It seems to absorb oil and dry up any bearing or sliding surfaces where it migrates. Care must be taken to design the next moving parts with adequate sealing and lubrication points.

- The .00025 inch thick aluminum foil worked as package covers but it fluttered in the high velocity air stream. It must be protected or slightly thickened to help maintain its integrity and uniformity under the heat sealing and subsequent manual handling.
- The heat seal wheel with a .020 inch diamond pattern apparently sealed well at the safe non-scuffing temperature of 250°F. Unfortunately, speeding up the large wheel rate in an effort to finish up the required number of packages proved to be a problem later. The temperature of the heat sealer must be related to the wheel speed or else the peel seal can open upon handling after it has cooled off completely. Although packages were inspected before storing for later assembly, a rather large number of leaky ones were found the following day in those made at the end of the run.

A redesign of the machine necessarily must include a positive heat seal wheel drive so that its pressure and temperature can be adjusted for the best seal without danger of its stopping and scuffing off the top of the package. It is running on a melt layer of polyethylene and only the sharp points of the knurl keep it from slipping all the time.

Near the end of the CS-2 loading the sliding vacuum manifold had become fouled with the agent and its friction increased markedly. The electric clutch in the drive wheel mechanism then began to slip periodically and required constant hand startups to keep going. As soon as the required number of packages were made, the machine was stopped, broken down and bagged up in polyethylene for later decontamination. The hood was washed so the assembly and banding equipment could be installed.

When the CS-2 packages were assembled to the bodies with rubber cement, the end-of-the-run leaky packages showed up. These leaks were mostly tiny faults in the heat seal, detected by squeezing the package. Once assembled, the bodies could be handled with minimal leaking even in the worst cases.

This leakage was a very serious problem and it was felt at first that the whole operation had been a wasted effort. However, when projectiles with leaky packages were banded and then had the banding cured by 300°F for three minutes all residual CS-2 was at least temporarily destroyed. The projectiles could be handled outside the hood area without special precaution.* The details of the heat-curing process will be discussed further in the breakband section of this report.

*When the packed boxes were opened several months later, however, the residuals had intensified and protective equipment and ventilation was required.

More than a month passed before there was time to bring the package machine back to the general laboratory area and carefully rewash all parts for reassembly. This was a very tedious job which should be avoided in any future work. Even after this decontamination the presence of the CS-2 residues were still apparent especially when the film heater and heat seal wheel were finally reactivated.

The electric clutch that had been failing during the last stages of the CS-2 loading apparently got some more oil or some other substance in it and was totally useless. Since only a week of Soft RAG production was allowable at the end of the contract, the motor was connected directly to the mold wheel and run without the convenience of the clutch. The final production yielded about 400 demonstration projectiles.

In summary, the package machine prototype proved the feasibility of the continuous rotary process. The 5 to 6 mil black polyethylene looks like a good package material and the 1/4 mil aluminum foil is entirely satisfactory for the cover. A careful redesign of the package machine incorporating the above suggested changes and remembering the needs of a CS-2 contamination process should yield a reliable production method of providing a payload package for the Soft RAG projectile.

Breakband

The breakband which holds the aerodynamic shape of the RAG projectile is an extremely important part. It must survive launch and about 5000 rpm during flight and yet break upon hard, soft, and grazing impacts. It must

be supple so it will not cut and yet have a low ultimate strain (1 to 2 percent) usually associated with brittle materials. Environmental tests require hot, cold, wet, and dry functioning. Against hard targets the SRP #3 did all of these things. But soft targets showed that the SRP #3 breakband was too strong.

In order to conform to the projectile body well and yet be an integral band, a wrapping process for the breakband was selected from many possibilities during the SRP #3 development. The XM-742 production banding prototype machine was a simple extension, again, of proven laboratory techniques. No wrapping equipment could be found commercially so the machine had to be designed from scratch.

Since it was known that the breakband had to be weakened to enhance soft target dissemination, the machine had to be able to wrap the projectile at the rate of about 10 to 30 wraps per inch, and also have the capability of wrap rate variation over the length of the projectile. The soft bodies had previously been carefully held during wrapping to prevent compression and distortion until they were dried. In the production concept projectiles are assembled alternately on holding mandrels for wrapping as a batch, dried and cured as necessary, and then cut off to provide clean edges for the band. It had been found that a circumferential slit just aft of the payload package aided in completely disseminating the payload upon impact. This cut is made at the same time.

The wrapping machine, like the package machine, had to be portable and of a convenient size and shape to fit into the 3 x 6 foot fume hood for CS-2 loading and banding. The requirements were presented to the Du Pont Engineering

Research and Development group at Remington Arms Company for detailed design, component specification and fabrication. This machine was also in operation two months after the start of the program.

A. Banding Material Requirements

As mentioned, the screening of banding materials was extensive in the development of the SRP #3. Cellulosic tissue (Aldex 17, Gould Paper Company, New York) was slit to 1/8 inch width, and run through an impregnator containing a water emulsion of ethylene vinyl acetate (Elvace® 1968 resin, Du Pont Wilmington, Delaware). Both the narrow width and the water wetting are required for a uniformly snug and integral banding over the curvature of the projectile. The EVA simply acts as a binder which in combination with the tissue produces a supple band whose tensile strength stays within 10 percent of its room dry value after soaking in hot (125°F), cold (0°F) and wet (90 percent R.H. at 120°F) conditions. The room and hot strains are about 1 to 2 percent whereas the cold and wet ultimate strains are typically 3 percent. The strain is most important since the total band strength can easily be adjusted by variation of the wrap rate.

The final necessary breakband characteristics could only be established as the result of launching survival, flight and biophysics impact test firings. It was felt that the inherent versatility of the wrapping process would allow the band to be trimmed up to any specification.

In order to be ready for the tight time schedule of this program, both tissue and EVA binder was ordered early. The narrowest tissue which could be slit on production equipment was 1/4 inch. Provision had to be made to fold this tissue exactly in half. The EVA originally was used as received with 50 percent solids. Since the SRP #3 was wrapped twice with

1/8 inch tissue at the rate of 20 wraps per inch, there was no problem with band integrity. But a single wrap of folded 1/4 inch tissue gave a band too soft (too much strain) and clearly not consolidated as well as the SRP #3. To regain breakband qualities of the SRP #3 design, a cross-linking catalyst of Oxalic Acid was added to the EVA to reduce the pH to 2.4. This change was made later on in the program and did produce a much more integral band.

B. Banding Machine Design

The whole breakband fabrication process involves several machine elements: tissue folder, impregnator, wrapping machine and band slitter. The first three are put into perspective with the schematic in Figure 21. It shows the tissue being taken off the roll through the folder and into a slack storage area. It is then pulled through the impregnator by the wrapping machine during the banding of six projectiles supported on sleeve mandrels that fit onto the machine.

To facilitate acquisition of tissue in a reasonably useful form, the paper company was allowed to put the 1/4 inch slit tissue onto six inch wide, three inch diameter cores. The rolls are 15-1/2 inches in diameter and quite massive compared to the 2-pound breaking strength of the dry tissue. The roll was, therefore, set horizontally on a low friction rotating base to be pulled off by the folder, shown in Figures 22 and 23. While the tissue could be pulled off the roll and folded very fast, the sporadic nature of the process would require synchronization of the feeds right through to the wrapping machine. This did not seem warranted within the scope of the program so the tissue was just folded slowly and continuously. The pile of tissue could then be drawn up into the wrapping machine at a much faster rate without fear of breaking the tissue.

The tissue then is pulled into the impregnator bath shown in Figure 24 where its breaking strength immediately drops to 1/2 pound from the 2-pound dry value. Little tension is allowed in the bath or squeegee. A band breakage would stop the process. The wetted tissue is then guided onto the wrapping machine by a low friction roller, shown in Figure 25.

The projectile banding is achieved by assembling the projectile bodies with the payload packages affixed with ordinary rubber paper cement and then alternately placing them on holding mandrels as shown in Figure 26. The aluminum tubing for these mandrels was sent to Edgewood Arsenal to expedite the fabrication of over 60 pieces on a numerical control lathe. These mandrels not only hold the body to the proper dimension but provide fixed length dimensions to reference the wrapping and subsequent band slitting during cutoff. Seven mandrel sleeves and six bodies are stacked together as a production batch and slid onto the shaft of the wrapping machine.

The requirements of the wrapping machine are quite straightforward. It must provide a rotating shaft to hold seven banding mandrels and the shaft must extend out freely from the machine at one end of the stroke to facilitate assembly and any other operations which might eventually be included in the process. The shaft had to be of variable speed up to 220 rpm. The thread rate had to be controllable as a function of movement and be tied directly to the rotation of the shaft so a wrap rate is independent of banding speed. The arrangement of the actual design is shown in Figure 27 and details are shown in Figures 28 and 29.

The motor and variable ratio gear box is mounted on a reciprocating carriage with a screw drive right off of the gear box. Although it has not been needed, the arrangement of the gear box ratio control is rotary with full range

adjustment in a quarter of a turn. This allows a cam surface to be introduced on the machine base to vary the wrap rate as the carriage moves. Almost any rate variation within 10 to 30 wraps per inch could be introduced repeatably on each of the six projectiles just by replicating the cam surface after each banding mandrel length. In practice, the gear box was just fitted with a calibrated dial so that banding rates from 10 to 20 per inch could be set without actually checking the wrap every time.

At the end of the wrapping stroke the carriage disengages a split nut to prevent collision with the base. The release is also handy for positioning the carriage manually and stationary rotation of the shaft for other process manipulations.

There have been no problems with the banding machine throughout this program. Since the wrapping stroke for six projectiles is less than a minute, the capacity of the machine is about 180 projectiles per hour, well above the production needs for the Soft RAG projectiles at this point. Final production machinery would, of course, be faster, hold more projectiles and be simpler to load and unload.

C. Banding Process

In practice the banding operation for the Soft RAG projectiles was done in batches of 48 and took about an hour for turnaround. The Elvace® 1968 resin was prepared in 1000 cc lots. The green color additive, Du Pont's Monastral® green dye B-GW-749P (Lot 39155 8/8/74 from Chambers Works, Wilmington), was added at one percent volume. Subsequently, the EVA was catalyzed by adding five percent of an oxalic acid solution (227.5 grams per 2.84 liters water), reducing the pH of the solution to 2.4. After the addition of the catalyst, the EVA solution lasts for approximately two weeks at room temperature.

Monastral® dye is a trademark of the Du Pont Company for a particular dye.

The banding process is initiated as follows: The tissue folder is started at a slow and steady rate, and then the tissue is threaded through the impregnator. The EVA solution is squeegeed from the tissue by a Nordel® elastomer rubber pad which is held by a leaf spring and compressed against a steel scraping edge. The compression of the rubber pad is adjusted until there is no film of EVA remaining on the tissue as it leaves the impregnator. To prevent the tissue from flipping over as it is wrapped onto projectiles, the guide roller must be kept clean and free running. To wrap the projectiles, seven mandrels and six projectiles are slid onto the banding machine shaft nose first and locked by a hand-tightened holding nut. When the split nut is released, the carriage moves to the starting position for wrapping the tissue at the end of the shaft. The tissue is hand threaded under the guide roller and over the top of the mandrel with about one full wrap for startup. The split nut is engaged and the machine accelerated slowly until the tissue firmly catches the mandrel and is wrapping. The machine is run between 3/4 and full speed until all of the projectiles are wrapped. The wrapping direction over the projectiles is tail to nose to cause a slight shingle effect facing toward the rear of the projectile for minimum aerodynamic drag. After wrapping, the split nut automatically disengages so the shaft just turns freely. To enhance consolidation of the wraps, the breakband is lightly wiped with a damp sponge or cloth. The whole assembly is then slid off the shaft as it is held in compression and set into a blower box for accelerated drying.

The drying operation requires about 15 minutes. The breakbands are then slit and the projectiles removed from the mandrels, using the slitter shown in Figure 30. To minimize projectiles sticking, the mandrels are periodically sprayed lightly with silicone mold release. If the projectiles do stick, this

sometimes causes permanent breakband distortion if the band gets stretched while still damp when removing the projectile.

The projectiles are then allowed to dry thoroughly overnight before the final curing. Three minutes at 300°F has been the usual treatment for the crosslinking of the EVA in the breakband when talc is used as a payload simulator. The special problem of crosslinking CS-2 loaded projectiles is discussed in the next section.

D. Breakband Production

In the initial phase, all banding was based strictly on experience gained with the SRP #3. The bands were wrapped at 19 per inch, allowed to dry for several hours, and then crosslinked for three minutes at 300°F. Subsequently, Edgewood Arsenal observed that the breakbands seemed to be softer, less brittle and less consolidated than the previous SRP #3's so the process was reevaluated and Du Pont consulted. The problem was found to be inadequate crosslinking. It was suggested that the bands be dried more thoroughly and that a catalyst be added to the EVA solution as is common in the textile industry. The overnight drying of the projectile and oxalic acid catalyst did indeed improve the band quality.

As the projectile body underwent variations in density and molding techniques, a number of different wrap rates were tried and tested until proof testing was carried out at Delco with the latest version launcher in November. Soft RAG's with bandings of 13, 15, 17 and 19 wraps per inch were fired with only one launching failure. These tests coupled with Edgewood Arsenal biophysics work allowed the XM-742 design to be tentatively frozen at 17 wraps per inch and the loading of the CS-2 projectiles to be done before the end of the year.

The requirement for thermal crosslinking of the binder used in the breakband had to be met without decomposing the CS-2 payload.

With the oxalic acid catalyst, crosslinking of EVA 1968 begins at approximately 250°F and requires 1 to 1-1/2 minutes at this temperature for the reaction to be completed. However, the crosslinking is statistical in nature with no absolute 100 percent crosslinked value achievable--some crosslinks will be degraded before all can be formed. The best that could be accomplished was to apply the accepted crosslinking temperature-time schedule and observe the performance of the projectiles during actual testing.

To determine approximately the heat transfer through the breakband and the risk of melting the CS-2 payload, a time/temperature test was devised utilizing a fine thermocouple (Cu-Const. with 0.015 inch diameter). This type of thermocouple has rapid response but it was found not to be fast enough to give instantaneous readings. When subjected to 300°F air it indicated 290°F in one minute. When sandwiched between two breakbands, the readings at each successive minute were 258°F, 287°F, and 291°F. It was concluded that the breakband reaches at least 250°F after one minute so another 1-1/2 minutes should provide adequate crosslinking.

To determine the actual temperature seen by the payload in the projectiles in 300°F air, the thermocouple was placed just under the aluminum foil of the payload package in a talc-loaded Soft RAG projectile. The temperature at each minute was 160°F, 193°F, and 208°F. At some time after two minutes of exposure to the 300°F air, the payload will reach 200°F. Naturally, if filled with CS-2, the CS-2 will begin to melt.

As was mentioned previously in the CS-2 Loading section, a leakage problem of the CS-2 from the packages did develop. Further, the package machine had been disassembled and it could not be restored quickly to operation. In an attempt to save these packages, it was decided to heat some of leaking CS-2 filled packages to 300°F for various lengths of time to determine if CS-2 would fuse the leaks. Six of the worst assembled bodies with severe CS-2 contamination were selected and banded as described. Two were crosslinked at 300°F for 3 minutes, two for 4 minutes and two for 5 minutes. The first two were cooled and inspected. They could be handled, sniffed, dropped and even bounced without leaking. The 300°F crosslinking temperature heat-cleans the contaminated projectile and apparently seals any leaks in the package under the banding. However, a thin crust (less than 1/16 inch) was formed over the top of the CS-2 in the payload cavities. The four-minute projectiles were half melted and fused and the five minute ones completely destroyed. This was clear evidence of the thermal gradient moving quickly into the projectile through the band.

A few more projectiles with leaking CS-2 packages were banded and cross-linked for only 2-3/4 minutes. When cut open, they showed only the thinnest crusting of the agent next to the foil and this was considered as the acceptable crosslinking and sealing condition.

The rest of the 500 projectiles were then to be crosslinked for 2-3/4 minutes at 300°F in a forced circulation oven. A few were inspected from time to time and they looked fine until a projectile from the edge of the 30-projectile rack batch was inspected. It was found to have melted unacceptably in about 1/3 of the payload cavities. (356 projectiles had been treated to this point.)

This problem resulted because when the oven door was opened to put in the projectiles, the temperature of the oven dropped momentarily, turning the heater's controls on. The oven operates with heaters much hotter than 300°F, and the air circulates non-homogeneously, at least on the crosslinking time scale, causing non-uniform heating of the stacked projectile bodies.

The crosslinking time was reduced even further to 2-1/4 minutes (a bare minimum), more time was allowed between batches and the in/out operation speeded up to a maximum to help maintain the oven control temperature. Since it was impossible to make more CS-2 filled packages within the schedule, 356 projectiles were entered into the test program with the understanding that some projectiles were unacceptable as the cavities of these projectiles had melted and fused improperly. The last 114 are presumably good.

Future breakband crosslinking will require much better temperature control, possibly by a fixed rate conveyor traveling through a uniform 300°F chamber.

No other CS-2 loaded projectiles were made during this program, and, indeed, there was no production of talc-filled projectiles at all until the end of January. The reason for the delay was the possibility that the breakband ultimate strain might be too high for good biophysics results. To alleviate this concern, a new drying procedure was incorporated into the fabrication of Soft RAG projectiles. After room drying and disassembly from the banding mandrels, the projectiles were force-dried at 125°F for one hour, cooled back to room temperature and finally crosslinked for 3 minutes at 300°F. After one hundred talc-filled projectiles were made like this, problems surfaced when test firings began with the final Delco launcher design.

With the new launcher every one of the Sting RAG's and about half of the Soft RAG's banded at 17 wraps per inch and cured as described above had some sort of failure from band cracks in the nose to complete breakage at the muzzle. Apparently, the payload package in the Soft RAG made it more resistant to failure. It was clearly determined that crisp dry breakbands (1-1/2 to 2 percent ultimate strain) could not be launched successfully in the new launcher.

As the program neared completion, the Soft RAG demonstration projectiles were banded with 20 wraps per inch, dried overnight and crosslinked for 3 minutes at 300°F. It is assumed that the results of breakband studies and projectile/launcher interaction derived from the Sting RAG program will eventually be incorporated into the Soft RAG.

XM-742 Production

During the course of this contract 1328 Soft RAG XM-742 projectiles were delivered to Edgewood Arsenal and several hundred more were made for special testing. To put the production activities into perspective with the design and process variations discussed in the previous sections the delivered projectiles are listed in Table 1.

As part of concurrent Sting RAG (designated XM-743) production, inspection criteria were set up for the delivered projectiles to be checked on a 10 percent random basis for body weight, outer diameter, inner diameter and length. The projectile's diameters were measured to within .010 inch by means of .010 inch stepped ring gauge. The length was measured similarly by a pin gauge also to within 0.010 inch. The CS-2 loaded XM-742's and the final shipment were inspected in the same manner. The actual results of the inspection for both types of projectiles are listed in Table 2.

Table 1

LIST OF XM-742 PROJECTILES DELIVERED TO EDGEWOOD ARSENAL

<u>Date</u>	<u>No.</u>	<u>Mold</u>	<u>Material</u>	<u>Binder (Green)</u>	<u>Wraps per Inch</u>
8/12/74	84	Steel	Plain Nordel® Elastomer	Plain EVA	19
9/11/74	36	Steel	Plain Nordel® Elastomer	Plain EVA	19
9/19/74	24	Epoxy	Nordel® Elastomer 17% Brass	Plain EVA	19
9/26/74	60	Epoxy	Nordel® Elastomer 17% Brass	Plain EVA	19
10/8/74	12	Epoxy	Nordel® Elastomer 17% Brass	Plain EVA	10
	12	Epoxy	Nordel® Elastomer 17% Brass	Plain EVA	11
	12	Epoxy	Nordel® Elastomer 17% Brass	Plain EVA	12
10/18/74	60	Epoxy	Nordel® Elastomer 30% Brass	Catalyzed EVA	10,11,12,24
12/18/74	470*	Epoxy	Nordel® Elastomer 30% Brass	Catalyzed EVA	17
1/23/75	114	Epoxy	Nordel® Elastomer 30% Brass	Catalyzed EVA	17
2/24/75	12	Epoxy	Nordel® Elastomer 30% Brass	Catalyzed EVA	17
	12	Epoxy	Nordel® Elastomer 30% Brass	Catalyzed EVA	20
	12	Epoxy	Nordel® Elastomer 30% Brass	Catalyzed EVA	24
	12	XM-743 (Epoxy)	Nordel® Elastomer 30% Brass	Catalyzed EVA	24,18 over payload cavities
	12	XM-743 (Epoxy)	Nordel® Elastomer 30% Brass	Catalyzed EVA	24
3/5/75	384 (Final Run)	Epoxy	Nordel® Elastomer 30% Brass	Catalyzed EVA	20

*These were the only projectiles with CS-2 loaded into the packages.

Table 2

SUMMARY OF INSPECTION DATA FOR CS-2 AND TALC-FILLED XM-742 PROJECTILES

	<u>CS-2</u>	<u>Talc</u>
Aver. Weight (grams)	34.6	33.8
Weight Extreme Variation (grams)	2.5 (7.2%)	3.17 (9.3%)
Weight Standard Deviation (grams)	0.63 (1.81%)	0.63 (1.86%)
Outer Diameter (inches)	2.44	2.445 (both $\pm 0.010"$)
Inner Diameter (inches)	1.75 - 1.77	1.75 - 1.77
Length (inches)	1.33	1.33 (both $\pm 0.020"$)

The difference in weight between the CS-2 and talc-filled projectiles reflects a heavier payload of at least 0.5 gram. The larger diameter of the talc-filled projectiles results because they were wrapped 20 per inch whereas the CS-2 projectiles were 17 per inch.

XM-742 Testing

As production machinery concepts were being developed a program of testing continued toward the optimization of the projectile characteristics and performance. At the end of the SRP #3 work the projectiles flew quite accurately out to 60 meters and disseminated 100% against hard targets. The main Soft RAG problem was dissemination against soft targets and grazing impacts. The variations in materials and designs therefore were centered entirely on the projectile body weight and breakband properties after the production process had been specified. Firing tests were the primary method of evaluating performance. Testing of materials was also conducted to determine the effects of process changes.

Since the RAG launcher was being developed concurrently, the testing device was subject to change along with the projectile. Some data from Sting RAG firings are included.

A chronological review of the projectile optimization test program is presented below:

6/18/74 The Delco Mark IV-6 launcher was fired with 11 grain blanks* (210-220 fps) at 40 meters. The projectiles were of the revised XM-742 design, molded in steel molds and hand banded at 19 wraps/inch with plain Elvace[®] resin 1968, crosslinked three minutes at 300°F. All four shots curved very badly to the left indicating poor spin coupling to the launcher cup.

* (All test firings were made from a Delco launcher on M16-A1 rifle using standard 5.56mm blanks loaded with 6-12 grains of Du Pont Hi-Skor[®] 700X powder.)

Hi-Skor[®] powder is a trademark of the Du Pont Company for a particular powder

6/22/74 To enhance the torquing of the projectile, the inner diameter of the launcher cup was filled with epoxy to form-fit the projectile. Of the first nine shots, five were nearly perfect and the others, satisfactory. Then the launch velocity slowed perceptibly as the cup began to experience excessive friction from deformation.

6/25/74 Additional projectiles were prepared in a similar manner and fired the same way at Edgewood Arsenal with another launcher without any epoxy fill of the inner cup. The overall results were very poor. There were numerous muzzle breaks and powder puffing, and the accuracy was poor.

6/26/74 Six more similar projectiles were fired from the Mark IV-6 launcher with the epoxy filled cup which had been straightened up and which had the epoxy sandblasted for better torque coupling with the projectile. The first five flew well to the 40 meter target and then the last broke at launch. The breakage was ascribed to either the projectile banding or possible interference with the launcher rifling lands.

7/9/74 R. E. Belden of Edgewood Arsenal observed the first machine banding of projectiles. They were banded at only 11 wraps/inch, air dried for about four hours and then fired. Eleven out of twelve flew accurately and disseminated 100% against the hard target at 40 meters and one broke at launch.

7/31/74 The remainder of the 11 wrap/inch projectiles of the previous test were crosslinked the next day and saved until this retesting. Every projectile broke on launch. Clearly, there was a breakband variation which was the source of the problem. It was known that the ultimate strain

of the breakband decreased from about 3% wet to 1-1 $\frac{1}{4}$ % when thoroughly dried even though the tensile strength was closely maintained. The strain tolerances were considered important to the final projectile/launcher interface design. Since the final launcher and cup were not yet ready no changes were made.

8/7/74 D. Chabot of Delco Electronics brought a new launcher cup to Remington which fit the projectile better but which was not to the dimensions agreed upon. Both Sting and Soft RAG steel molded projectiles were wrapped at 20 wraps/inch, dried overnight and crosslinked as usual. The bodies for both were the same unfilled Nordel® elastomer and the Soft RAG's weighed 28.8 grams. The Sting RAG's were about 3 grams lighter without the payload package. The 11 grain blank loads fired these at slightly over 210 fps at 40 meters. Seven Sting RAG's and four Soft RAG's were launched and flew satisfactorily from this launcher. A few shots on a shallow graze angle with the asphalt yielded mixed results. Some opened with over 50% dissemination and others not at all.

8/13/74 More Soft RAG projectiles were made but with 19 wraps/inch and fired with 11 grains of powder from a second cup exactly like the last test. Eight good straight shots resulted at 40 meters with excellent 100% dissemination against the hard target.

All projectiles to this point had been molded from unfilled Nordel® elastomer in steel molds.

9/3/74 At the direction of Edgewood Arsenal the final projectile weight was to be increased to 33.5 grams from the present 29 grams. To maintain the Soft and Sting RAG projectiles to the same final ballistic

weight, it was decided to fill the Soft RAG Nordel® elastomer with 17% brass powder and the Sting RAG with 30%. Work on the epoxy production molds was nearing completion and it was planned to use them in the further projectile production together with the steel mold for comparison.

9/18/74 R. E. Belden of Edgewood Arsenal brought another launcher cup, shaped better but still too small on the I.D. Eight strips of tape were therefore added to the inner cup portion to fill up the interface. A number of steel molded projectiles were then fired from the same Mark IV-6 launcher.

Four shots with 11 grains of powder producing velocities over 210 fps were fired using unfilled Nordel® elastomer bodies wrapped 19 wraps/inch. All flew straight and had 100% dissemination against a hard target. One each of 17% brass-filled Nordel® elastomer wrapped 18, 16, 14, and 12 wraps/inch were then checked. All flew very well except for a 16 wraps/inch which broke in flight.

To check soft target dissemination at 40 meters, a steel drum filled about two thirds with water and capped at each end with a 15-inch diameter rubber membrane was conceived and checked by Edgewood Arsenal Biophysics personnel. But this soft target simulator had to be hit within an inch of the designated impact point to be a valid simulator. Since this was difficult to do at 40 meters, the simulator was fired at about 10 feet with only 6 grains of powder. This gave velocities of about 150 fps at the muzzle, about the same as the normal launch after 40 meters flight.

A precheck of hard target dissemination at these lower velocities was made at close range with the unfilled Nordel® elastomer, 19 wraps/inch projectiles. All three projectiles disseminated 100%.

The soft target simulator was set up in a range where the muzzle velocity could be measured. Firings were conducted with projectile bodies without the brass filler and with 17% brass. Firing results were described below:

- Unfilled Nordel® elastomer, 19 wraps/inch @ 152 fps--no break or dissemination
- Unfilled Nordel® elastomer, 19 wraps/inch @ 175 fps--more than 50% dissemination
- 17% brass-filled, 18 wraps/inch @ 144 fps--partial break and 30% dissemination
- 17% brass-filled, 16 wraps/inch @ 144 fps--partial break and more than 50% dissemination
- 17% brass-filled, 14 wraps/inch @ 144 fps--partial break and more than 50% dissemination
- 17% brass-filled, 12 wraps/inch @ 144 fps--no break, band accordion-wrinkled
- 17% brass-filled, 18 wraps/inch @ 166 fps--broke and more than 75% dissemination

The test was terminated with partial results as the rubber of the simulator was punctured.

Shortly thereafter Edgewood Arsenal shot a number of projectiles, banded at different wrap rates, at a specially clothed dummy. No breakage or dissemination resulted. It was observed that the breakband was too supple and not brittle enough.

10/3/74 In order to check the breakband effect on soft target dissemination a set of 64 projectiles, 17% brass-filled, was molded in a steel mold.

There were 16 each of 13, 15, 17, 19 wraps/inch. Half were prepared normally and the other half soaked for 40 hours at 170°F to make sure the bands were thoroughly dry.

The soft target simulator was repaired with a thicker rubber supplied by Edgewood Arsenal. R.E. Belden of Edgewood Arsenal observed and recorded the test results.

With 6 grains of powder in the blank, velocities around 150 fps were attained. All projectile types functioned against the simulator with 30 to 100 percent dissemination. There was no trend with wrap rate nor difference due to dryness of the second group. The only difference between the two groups was that the hot soaked projectiles generally took all of the aluminum foil off the payload package whereas the normal ones left remnants at the heat seal.

Additional grazing tests were made at 215 fps at 5 degrees onto smooth concrete right into a soft catcher. All 13, 15 and 17 wrapped projectiles functioned about the same, with approximately 50 to 100 percent dissemination. The 19 wraps/inch projectile did not disseminate appreciably so the 17 wraps/inch was selected as the best wrap rate for dissemination and launch survival.

10/4/74 Additional dried 19 wrap/inch projectiles were fired at Edgewood Arsenal against a clothed Styrofoam®, cellular plastic, dummy still with no significant dissemination.

10/5/74 Because the projectile bodies molded in the production epoxy molds were about .015-.020" smaller in diameter than the steel molded counterparts using the 17% brass-filled Nordel® elastomer, the final Soft RAG weight was around 32.5 grams. Edgewood Arsenal decided that even more ballistic weight would be desirable (34.5 grams) so the Soft RAG was molded from this point on with the 30% brass-filled Nordel® elastomer. In order to make the Styrofoam® cellular plastic is a trademark of the Dow Chemical Company for a particular cellular plastic.

sting RAG the same weight, the payload cavities were shallowed by 0.075" to a 0.175" depth.

10/16/74 Consultation with Du Pont resulted in the recommendation that the EVA breakband binder be catalyzed with Oxalic acid to decrease the normal 4.2 pH to 2.4. This produced better crosslinking and breakband integrity.

10/22/74 Further breakband binder investigation involved the variation of the percent solids. The plain EVA 1968 is produced as a 50% solids water emulsion so samples with 40, 30 and 20% were also made with 10, 15 and 20 wraps/inch. In the dry condition there was no difference in the ultimate strain or tensile strength for the 15 and 20 wrap/inch samples. But wetted tensile samples showed a definite decrease in strength with decreasing percent solids. It was therefore agreed to stay with the 50% solids binder formulation.

10/23/74 D. Chabot of Delco brought a prototype of the latest launcher design for testing. Instead of rifling lands in the barrel, grooves were introduced and little keys affixed to the launcher cup. This, among other things, was to insure that there was no projectile/launcher interference on exiting the muzzle. Unfortunately, the inner cup diameter was still too small so the first three shots with 11 grains of powder curved very much to the left indicating poor spin coupling or precession. Eight .007" thick, 3/16" wide strips of tape were placed in the inner cup for a better fit and the testing continued. The next three shots were very good but then got progressively worse as the cup became tight in the launcher due to key galling and cup distortion. Also, the projectiles still could not be set in squarely very easily.

To check longer range accuracy and projectile/launcher effects, tests were made at 90 yards. The flights got progressively slower with larger left hooks. (Later muzzle velocity measurements showed that the increased cup/barrel interference had dropped the velocity from the normal 210-215 fps to 190-195 fps.)

An important sidenote of this testing for Soft RAG dissemination arose when two Sting RAG's were deliverately fired into grass for the first time at Remington Arms--one band came off and the other cracked in three places. This indicated that Soft RAG grazing dissemination would be enhanced greatly as the roughness of the target surface increases.

Later R.E. Belden observed some firings into the clothed Styrofoam® cellular plastic dummy. Low velocity (150 fps) 10 wrap/inch would not survive normal launch conditions. Some special wrapped combinations of 10 and 20 wraps/inch on a single projectile were also tested at low velocity with no difference from the 19 or 24 wrap/inch nominal dissemination.

Then all projectiles began breaking at the normal launch velocity so the tests were terminated.

10/29/74 Since the final launcher version had slightly increased spin from previous launchers, it was decided to determine the maximum spin rate that projectiles could withstand. A number of 30% brass-filled projectiles were wrapped at 13, 15, 17, and 19 wraps/inch and dried thoroughly for two hours at 125°F to produce the minimum ultimate strain in the range of 1-1/2 to 2 percent. They were then spun up on a special mandrel attached to the top shaft of a high speed (10,000 rpm max.) drill press. No projectile break-

bands broke and the spins were definitely over 9000 rpm. In fact, repeated sharp blows were required to break the spinning band.

It was therefore concluded that the muzzle launching failures had to be due to some dynamic projectile/launcher interaction during the launching acceleration. Unfortunately there was no data available at this time on the final launcher acceleration dynamics, so the problem could not be resolved.

11/1/74 Edgewood Arsenal, in reviewing all of the Soft RAG dissemination data, stated that Soft RAG's with 19 wrap/inch disseminated acceptably. Projectiles wrapped to this rate would be acceptable, but only subsequent to verification by Biophysics testing.

11/5/74 Since there was concern over the projectile breakage at launch, the breakband properties had to be checked more thoroughly. A number of projectiles were wrapped at 20 wraps/inch, room-dried 24 hours and then crosslinked three minutes at 300°F. (All EVA binder was catalyzed from 10/16). Hot aging tests then began at 125°F. Tensile specimens were made later by cutting off 10 wraps of breakband right over the payload cavities to form a 1/2" by 7" strip. The test length was 6".

11/7/74 Edgewood Arsenal's Biophysics testing showed that both 15 and 17 wrap/inch Sting RAG's were causing damage at velocities above the designated muzzle velocity of 210 fps. Drying the bands thoroughly at 140°F tended to improve the performance.

11/21/74 A trip was made to Delco with M. Miller of Edgewood Arsenal to determine the launching survival and flight characteristics of variously wrapped Sting and Soft RAG's in the latest final version launcher. In tests at Delco, 12.0 grains of powder in the 5.56mm blank were employed producing velocities in the range of 205-210 fps.

About three dozen 20 wraps/inch Sting RAG projectiles from the first 1000 delivery were fired at 40 and 80 meters. Survival and flight was 100% successful. At 80 meters, the projectile fired at 2-1/2 degrees elevation hooked about one meter to the left. With proper sighting a man could easily be hit at 80 meters. This was much better than the "group" accuracy required at 60 meters.

An additional three dozen projectiles had been brought with 15, 17, and 19 wraps/inch on Sting and Soft RAG bodies, all projectile bodies were filled with 30% brass. All projectiles were fired and flew exactly the same as the previous ones. Most projectiles were caught softly by a golf net but a number of Soft RAG's were purposely grazed on the ground. About 50% opened with 100% dissemination, yielding a very nice cloud of talc. The others did not open at all, indicating a strike on a smooth spot on the ground.

These firing tests were made at Delco during a period of exceptionally high humidity which increased the yield strain of the breakband appreciably. As a result, the breakbands performed better, with no ruptures, than they did in later tests under dryer ambient conditions.

12/4/74 The specimens made on 11/5 were prepared for tensile testing as a part of the continuing examination of the breakband properties. Before presenting the tensile data shown in Table 3, it should be noted that ring gauge outer diameter measurements showed no projectile shrinkage from the initial condition to the 24 days soaking at 125°F.

TABLE 3

Hot Storage Tensile Tests

<u>Time at 125F</u>	<u>Break Force</u> (Lb./Wrap)	<u>Tensile Strength*</u> (psi)	<u>Ultimate Strain</u> (%)
Initial	2.85	3800	2.08
Initial	3.0	4000	2.28
3 days	2.85	3800	1.6
3 days	3.0	4000	1.7
4 days	2.55	3400	1.6
4 days	2.43	3240	1.5
6 days	3.25	4333	2.0
24 days	2.7	3600	1.55
24 days	2.55	3400	1.5
24 days	2.4	3200	1.35
24 days	2.9	3866	1.75
24 days	2.25	3000	1.3
24 days	2.85	3800	1.6

Clearly the hot aging reduces the ultimate strain from about 2% to the 1½% range. But the larger sample number of the 24-day group shows how much the data can vary. Plans were laid then to investigate the short time drying effects in more tests.

12/10-18/74 All activities involved the loading, assembly and wrapping of the CS-2 loaded projectiles.

1/17/75 Continuing the investigation of the breakband properties it was thought desirable to check possible process revisions which would insure that the breakband repeatably had the lowest ultimate strain to improve dissemination efficiency. Since the projectiles would be sealed in a clip until used it was felt that a dry condition could be maintained.

A large number of Sting RAG projectiles were banded at 17 wraps/inch, the final wrap rate design designation, and processed in various ways as shown in Table 4 along with the tensile data. In Table 5, average tensile data is shown for breakbands cured by the normal cycle.

* Tensile Strength is based on a nominal .003" x 1/4" cross section per wrap.

TABLE 4

Tensile Tests on Breakbands Cured at Various Cycles

<u>Cure Schedule</u>	<u>Break Force</u> (Lb./Wrap)	<u>Tensile Strength*</u> (psi)	<u>Ultimate Strain</u> (%)
Overnight dry	2.80	3733	1.93
3 min. @ 300F	3.05	4066	1.6
	2.75	3666	1.46
Same	3.15	4200	1.61
30 min. @ 125F	2.35	3133	1.38
	2.20	2933	1.07
5 hour room dry	2.05	2733	1.01
3 min. @ 300F	2.00	2706	1.03
30 min. @ 125F	2.20	2933	1.16
1 Hour room dry	2.60	3466	1.4
15 min. @ 125F	2.65	3533	1.35
3 min. @ 300F	2.55	3400	1.31
1 Hour room dry	2.00	2635	1.0
30 min. @ 125F	2.85	3800	1.5
3 min. @ 300F	2.00	2640	0.93
1 Hour room dry	1.50	2000	0.66
45 min. @ 125F	1.60	2133	0.93
3 min. @ 300F	1.95	2600	0.98
1 Hour room dry	1.60	2133	0.88
60 min. @ 125F	2.10	2840	0.96
3 min. @ 300F	1.75	2333	0.93
Overnight room dry	3.20	4293	1.92
3 min. @ 300F	3.20	4266	2.05
Same	2.95	3933	1.8
60 min. @ 125F	3.00	4040	1.7
Same	3.15	4200	1.73
90 min. @ 125F	2.65	3533	1.52
30-60 min. room dry	2.00	2720	1.05
60 min. @ 125F	1.65	2200(misaligned)	0.75
room cool	2.85	3827	1.21
3 min. @ 300F	3.20	4266	1.31
	2.55	3400	1.1
	3.30	4400	1.61

* Tensile Strength is based on a nominal cross sectional area of
10 x 1/4" x 0.003" or .0075 sq. in.

TABLE 4 (Cont'd.)

<u>Cure Schedule</u>	<u>Break Force</u> (Lb./Wrap)	<u>Tensile Strength</u> (psi)	<u>Ultimate Strain</u> (%)
8 Wraps off	3.15	4216	1.51
Sting RAGs	3.35	4450	1.80
30-60 min. room dry	3.25	4333	1.73
room cool -one hour	3.25	4333	1.51
3 min. @ 300F	2.90	3866	1.60
	3.15	4222	1.58
	3.80	5050	1.83
	<u>3.85</u>	<u>5116</u>	<u>1.78</u>
Average	3.43	4573	1.67

Obviously the pre-heating of the projectiles right before crosslinking has a very strong effect on the ultimate strain and tensile strength. In fact the marked decrease in the tensile strength is undesirable. After analyzing the results, it was concluded that starting the projectile at 125°F instead of room temperature might be producing too much crosslinking thus degrading the band. So the test was repeated on 1/27/75 to check the statistics. Before the crosslinking, though, the projectiles were allowed to return to room temperature.

This process technique then provided low strains in the 1½-2% range while maintaining the tensile strength at a good high level.

1/31/75 Up to this point, tests at Delco resulted in about 4% muzzle breakage in the delivered Sting RAG projectiles. A Sting RAG specification meeting was then held at Edgewood Arsenal. At the conclusion a series of firing tests were made to check some small modifications of the final launcher and projectile.

Sting RAG projectiles with 17 wraps/inch were selected from the production lots for maximum and minimum diameter to see if wrapping tension could be causing a difference in the launch and accounting for the high breakage

rate. Both the large and small diameter projectiles flew slow and dropped off to the left. Older 20 wrap/inch flew down to the target but were notably inaccurate. Then the newer 17 wrap/inch pre-heated at 125°F before cross-linking all broke at launch and 2 out of 10 Soft RAG's with 17 wraps/inch broke at launch.

More projectiles were fired and caught in a muslin cloth. All bands broke in some manner. Projectiles were also tested concurrently out at Delco with similar results.

2/4/75 Edgewood Arsenal reported projectile distortion being observed in some of the high speed movies taken previously. It was thought that possibly some variation in the banding tension during the wrapping process could be causing this. It was found that the guide roller on the wrapping machine had been reversed to keep it from spinning during the banding operation to prevent tissue flipping. This was found to indeed be causing more tension variations, resulting in smaller projectile diameters, especially on the first two of the six projectiles being banded. At the start the guide was dry and somewhat sticky from the previous wrapping, so at start-up the tissue sees a larger drag force until the guide is wetted again. This procedure was immediately corrected so it was a free running guide.

2/5/75 To study further the breakband breakage problem, Edgewood Arsenal directed that a test matrix of Sting RAG projectiles of all possible process variations be fabricated. In addition, a number of projectiles was made with a strip of aluminum foil under the banding and some with a 5/8" wide strip of 1/32" thick polyethylene foam to determine if this could reduce this problem since fewer breaks resulted with the Soft RAG projectiles.

2/7/75 Delco test fired 60 of the final 17 wrap/inch Sting RAG design and had 100% failure by band breakage.

2/7/75 Every aspect of the RAG body and banding was then reinvestigated. It was suspected possibly that the rubber body properties might be differing so tensile tests were set up to find out. Bodies were screened for Shore "A" durometer until samples with 32, 34 and 35 were found. As durometer went from 32 to 35 the relative modulus of the bodies increased approximately 100%. Either there was a variation in the rubber itself or in the cure. The latter was determined to be the problem, and low durometer bodies could be stiffened by added exposure to heat. The number of projectiles in the Sting RAG test matrix was therefore doubled by repeating all conditions with bodies that were post-cured one hour at 300°F.

2/12-13/75 The Sting RAG test matrix firings began at Edgewood Arsenal. (Figure 31 shows a copy of the test matrix for reference) Every shot of the first run through was recorded on both high and low speed film, the velocity monitored and even the accuracy by noting the strike position on a large gridded target right behind a golf net catcher.

No projectiles survived without breaking until the ones with aluminum and foam underlays were tested. Then there was either no break or entire breakage in flight.

After discussing the situation at length it was suggested that the weather was very cold and dry so the projectile breakbands could be drying out. This would make them more brittle. Six normal 17 wrap/inch projectiles were humidified at room temperature overnight and fired the next day. All flew well with no breaks.....but the ultimate strain was later measured to be about 3% instead of 1½% of the average. This, of course, would be

detrimental to Soft RAG soft target dissemination.

Obviously, the larger strain of the breakband was more forgiving of the launch dynamics and could survive. From the high speed movies of firing tests three distinct sources of breakband failure were apparent: inadequate inner cup support for the projectile, sticking of the projectile to the inner cup, and too much of tolerance gap between the projectile and the outer cup support.

At this point the remedy for the projectile/launcher failure is strictly up to the Sting RAG system contractor. The Soft RAG funds were almost expended so only this report could be written after a final week of Soft RAG production to provide Edgewood Arsenal with demonstration projectiles.

Whatever action is taken to correct the system for successful Sting RAG performance, it will have to be reviewed later with respect to the needs of the Soft RAG.

FUTURE WORK

Any modification of the XM-742 Soft RAG projectile will necessarily have to await the large scale system testing results with the current configuration. This largely is dependent on the availability of the XM-234 launcher with stablized performance characteristics that will reliably launch the RAG projectile. At this point, there is no functional design change that should be recommended. If the projectile can be smoothly accelerated and released from the launcher, the flight accuracy and dissemination will be satisfactory for a riot control system.

The production of much larger quantities of projectiles for the continued engineering development phase of the Soft RAG will require expansion and further development of the three manufacturing areas: the body, the package and the breakband. While the detailed recommendations have been already presented the general activities are summarized below.

The Body

- Finalize the material selection and densification means with respect to functionality in the projectile, processibility and availability.
- On the basis of the required production schedules determine the best production system: injection molding, multiple press transfer molding or multiple mold single transfer molding as was used in this program. Besides capital needs and economic considerations the precise geometry and weight requirements of the RAG projectile have to be strongly included.
- Develop the mold design further to enhance repeatability and reliability especially by the introduction of several unbiased outside opinions.

- If synthetic non-metal molds are selected then develop their fabrication process using the information gathered in this program. But whatever the process, the complexity of the RAG part will require close attention to be paid to the economies of the tooling method.

The Package

- A complete reconstruction of the packaging machine is required to produce packages reliably.
- Modifications of the components should be made as follows:
 - Improve the heater control and uniformity.
 - Make the mold wheel a continuous series of cavities with no interruptions and introduce overall temperature control for long term stable operation.
 - Determine the vacuum controls which will insure the deep draw uniformity in the cavities.
 - Suspend the loading hopper so it can be readily adjusted and provide cut-off close to the filling end.
 - Provide the heat seal with a direct synchronized drive to the mold wheel, possibly widening it to eliminate residue agent on the package surface.
 - Provide independently adjustable width cutters.
- Redesign the machine frame, component disposition, drives, controls and accesses with respect to the containment requirements of the CS-2 agents. Depending on the projected residue anticipated in the revised design, special attention needs to be paid to all bearing and sliding surface seals.

- A package length cutter has to be introduced somewhere in the production operation, possibly before the assembly station.
- The detailed operating procedure including maintenance, material handling and scrap removal must be laid out as a basis for design revision and overall work area specification.

The Breakband

- The present machine can steadily produce 180 projectiles/hour and maybe more with adequate supply fixturing so it would suffice as is for quite some time.
- Larger production could be obtained by either enlarging and speeding up the present design or simply replicating it.
- There is much latitude in how the whole banding process can be set up, and how much it has to be automated. The production economies have to be established for both Soft and Sting RAG projectile needs.
- Breakband binder crosslinking needs to be done under very controlled time-temperature conditions when CS-2 is being loaded.

Since there is a possibility that the Soft RAG will be loaded with other simulants or payloads than the CS-2 agent, the compatibility of these materials with the present manufacturing process will have to be included in a total production scheme. Further, Sting RAG production may also be ultimately combined with the Soft RAG so it also should be considered.

The containment and handling of the CS-2 agent demands a very careful, detailed production layout which accounts for all contingencies.

APPENDIX

XM-742 LOADING CLIP

The Soft RAG loading clip was simply fabricated from aluminum tubing and polyethylene exactly as proposed in the experimental development program and described the final report.* The design is shown in Figure 32. While aluminum tubing was acquired to produce 10 prototypes it was anticipated that a laminated paper material would eventually be custom made to the required dimensions and material property specifications.

One prototype was made and determined to function correctly. It was given to Edgewood Arsenal for appraisal.

Since another loading clip concept was selected, Edgewood Arsenal directed a termination to all activities in this area.

* Kenneth W. Misevich, "Design Study for Soft RAG Projectile," Remington Arms Company, Incorporated, (AB 74-3), Bridgeport, Connecticut. (Work was supported and monitored by the U.S. Army, Edgewood Arsenal, Maryland, under Contract No. DAAA15-73-C-0047.)

**KM 742 SCHEDULE
(DAAA15-74-C-0221)**

**SFP #3
DESIGN
REVIEW**

	3/5	5/13	5/20	5/27	6/3	6/10	6/17	6/24	7/1	7/8	7/15	7/22
MAKE												
TEST		Establish Test Plan (Established Separation)			Make Prototype Package Mold Prototype Bodies Bond Banding							Hold Bodies Machine Test Machine Band
	Review Design and Build	Build	Check		Rollout Accuracy Discontinuation Institute Materials Tests			REPAIRS & REVISE			Test: Accuracy Discontinuation Start Environmental Tests	REPAIRS & REVISE
BODY		S Mold Concepts P Loading Mechanism C Cutting Requirements T Strip & Cut	Design Masters Design & Order Parts Order Parts (Hand Operation for Prototypes)	Build		Fabricate Prototype Mold Build Assemble Check		Hold & Review		More Holds		
	Order Sample & Machine									Use	Use	Use
PACKAGE		Review Mold Design Build Check	S Forming Mechanism P Filling Mechanism C Cutting Mechanism T Strip Mechanism S Forming Mechanism P Filling Mechanism C Cutting Mechanism T Strip Mechanism	Preliminary Design & Parts Order	Design & Build	Order Film Check and Assemble as Ready				Have to CS Area		
						Order Materials Design Order Materials	Design Necessary Build Check &			Fitures — Build, Check, Incorporate	Check Design	
BANDING		Build Thermo Welder/Folder										
	Layout Assembly Order Sample Machine	S Integrator P Tension & Guide C Caping T Tension & Guide S Integrator P Tension & Guide C Caping T Tension & Guide	Design Order Parts Design & Build Design & Build Design & Build Design & Build Design & Build	Build Design Design Design Design Design Design	Lab Check Use Check Assemble Use Check Assemble Use					Use		
CS-2	Formal Area Layout	Build Enclosure Order Materials				Secure Area & Write S.O.P. Install Equipment						
CLIP	Review Design			Specify Materials & Design	Fabricate Prototype	Check		REPAIRS & REVISE			Review, Fabricate w/ Prototypes	

GO

K.W. Misevich
Remington Arms Company, Inc.
May 3, 1974

FIGURE 1

Reproduced from
best available copy.

PLANT SHUT DOWN




SPECIAL
DELIVERY

FIGURE 1

 β

FIGURE 2

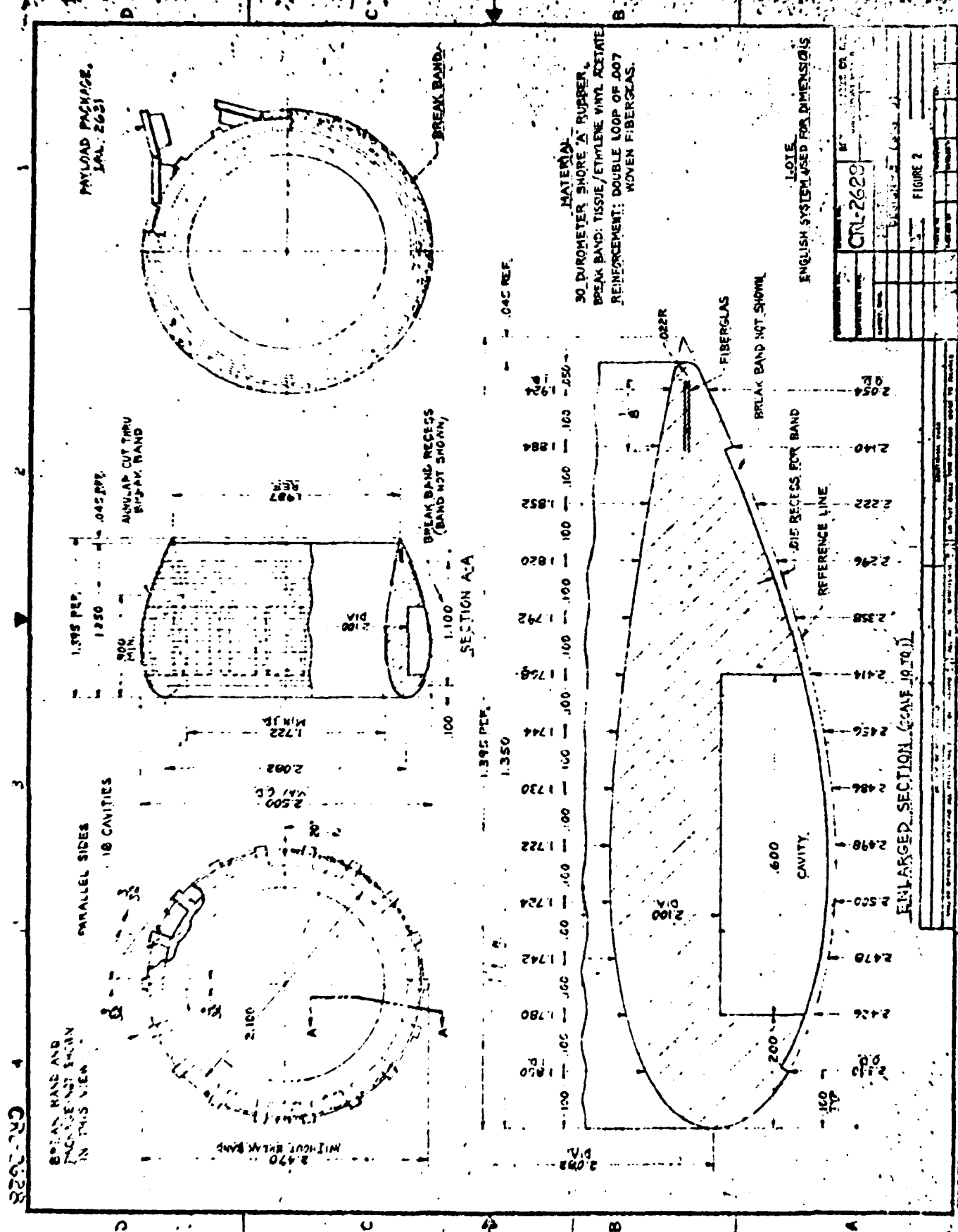


FIGURE 3

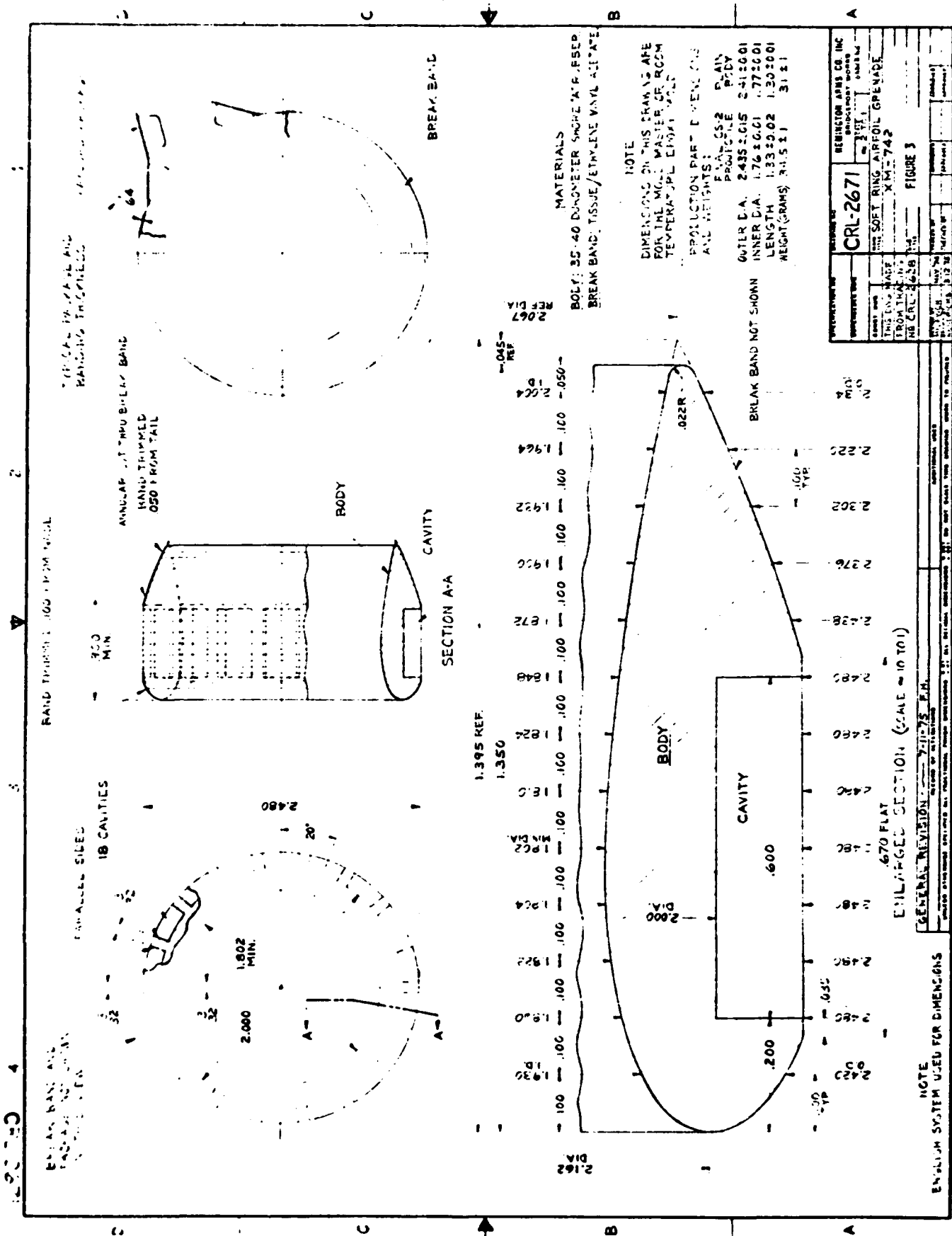


FIGURE 4

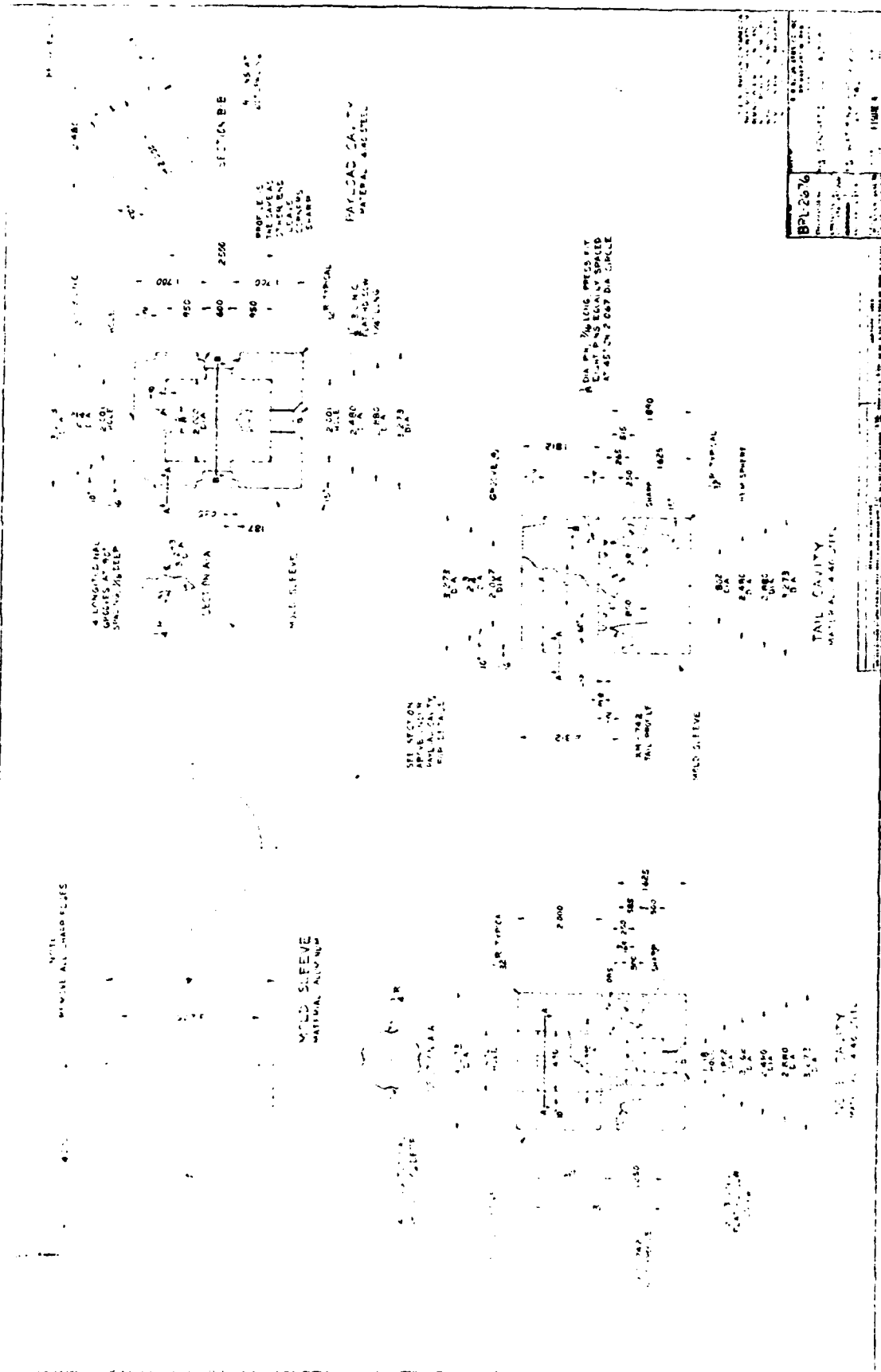


FIGURE 5

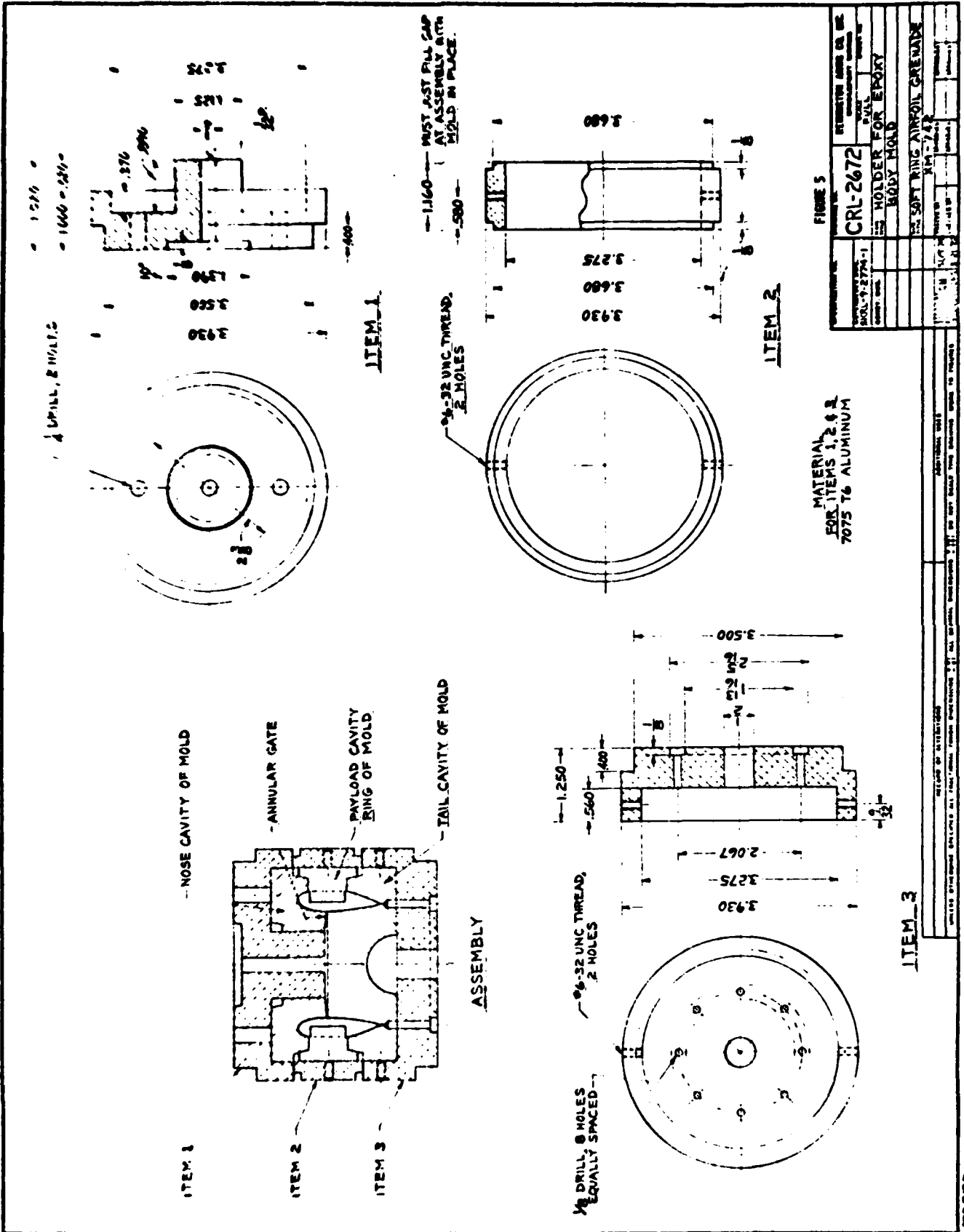
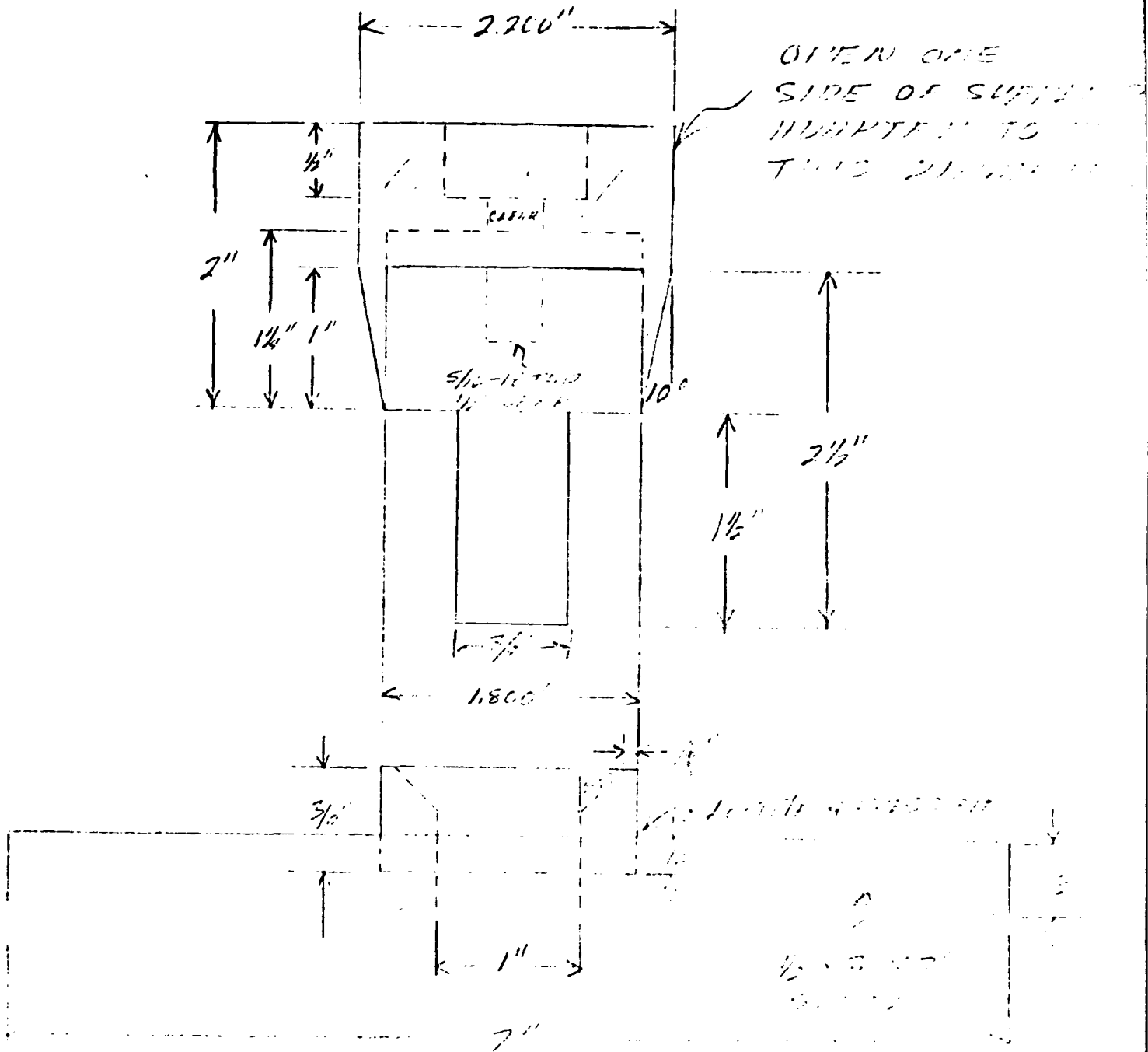


FIGURE 6

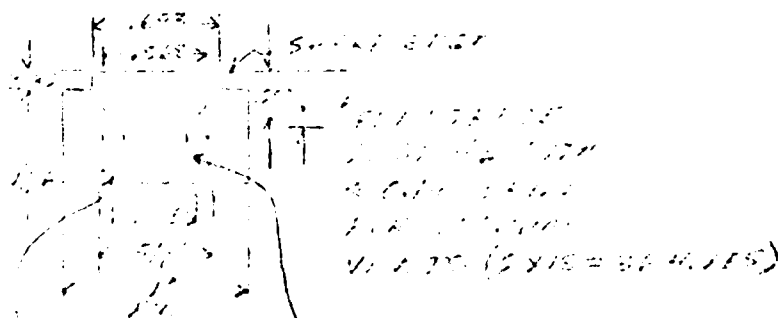
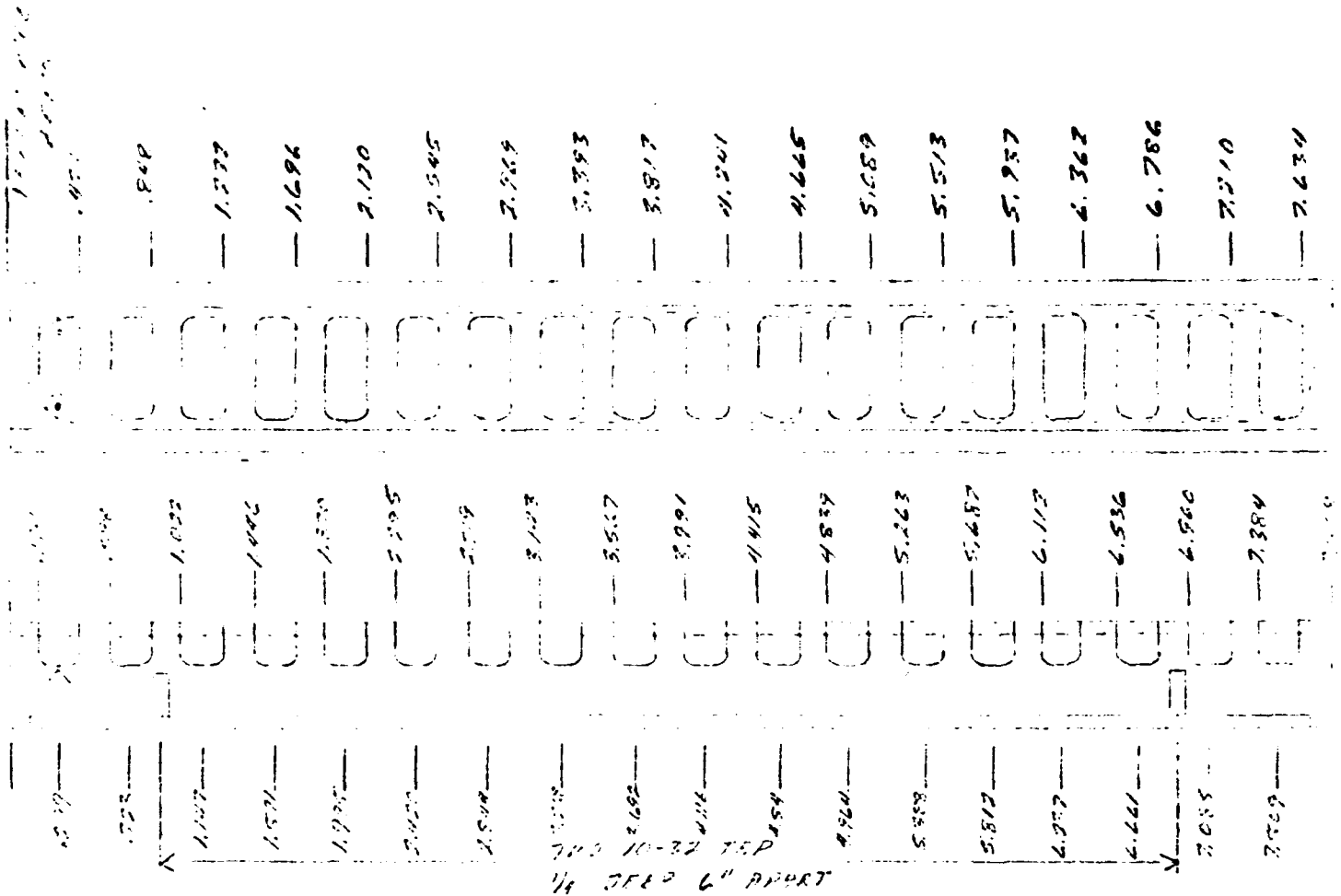


81-17078-112

NOTE FROM
 REMINGTON ARMS CO.
 STALL - HEAT TREAT

REMINGTON ARMS CO., INC. -- EPT., CO.		
RESEARCH & DEVELOPMENT DEPT.		
RNG SPRUE CUTTER		
DRAWN	APPD	DATE
SKRL 11-1877-1		

MATERIAL : STAINLESS STEEL ($\frac{5}{8}$ " x 1" x 7.808")



4/8 PEMA
TO WITHIN
4/8 54 8 178
507700

REMINGTON ARMS CO., INC., - DPT., COM
RESEARCH & DEVELOPMENT DEPT.

X11-742 PROTOTYPE
PACKAGE MOLD

DRAWN	APP'D	DATE
-------	-------	------

SERIAL- 5-278-1

31-17078-102

FIGURE 8

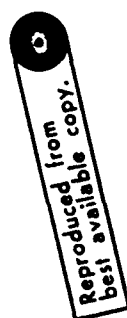
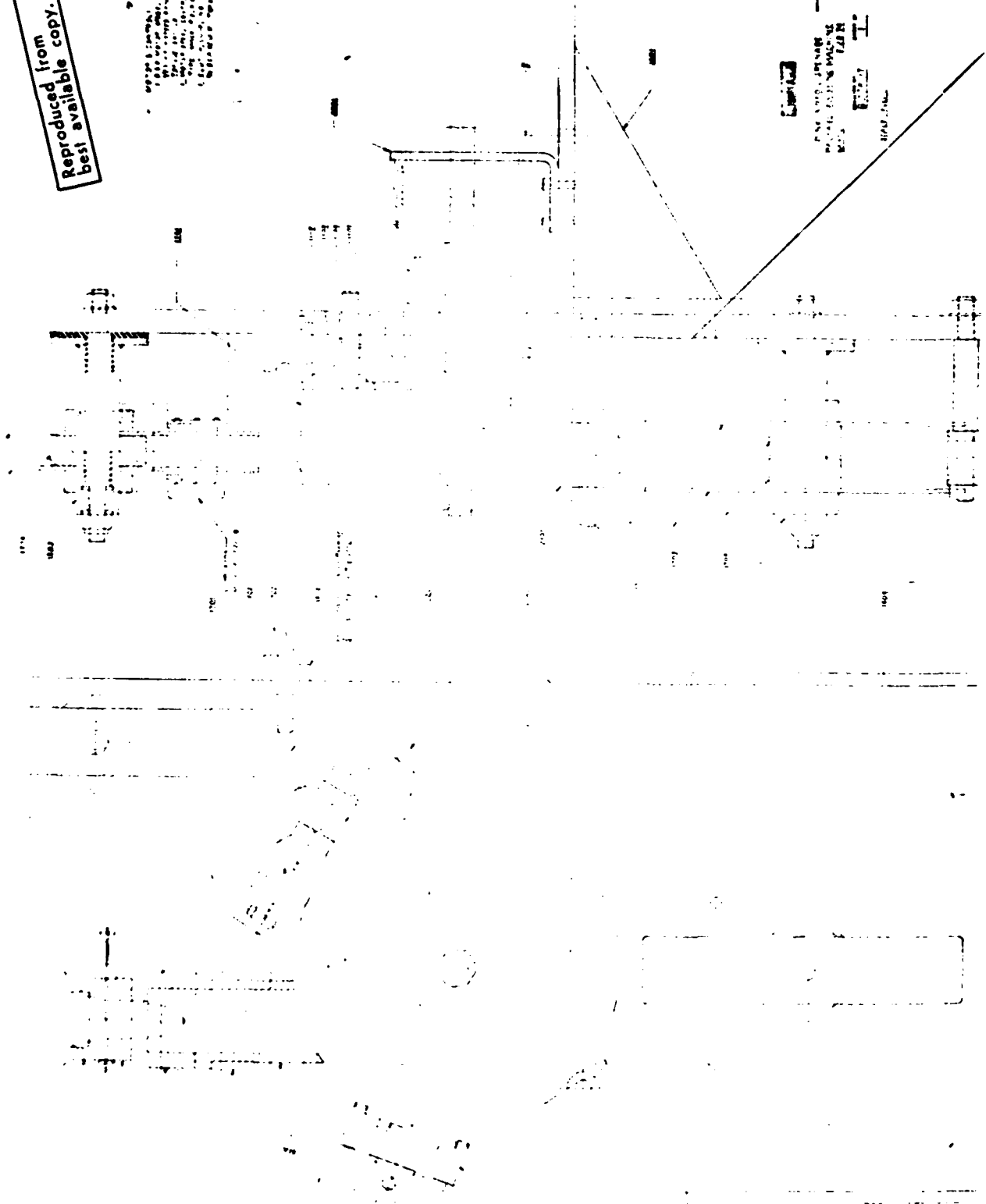
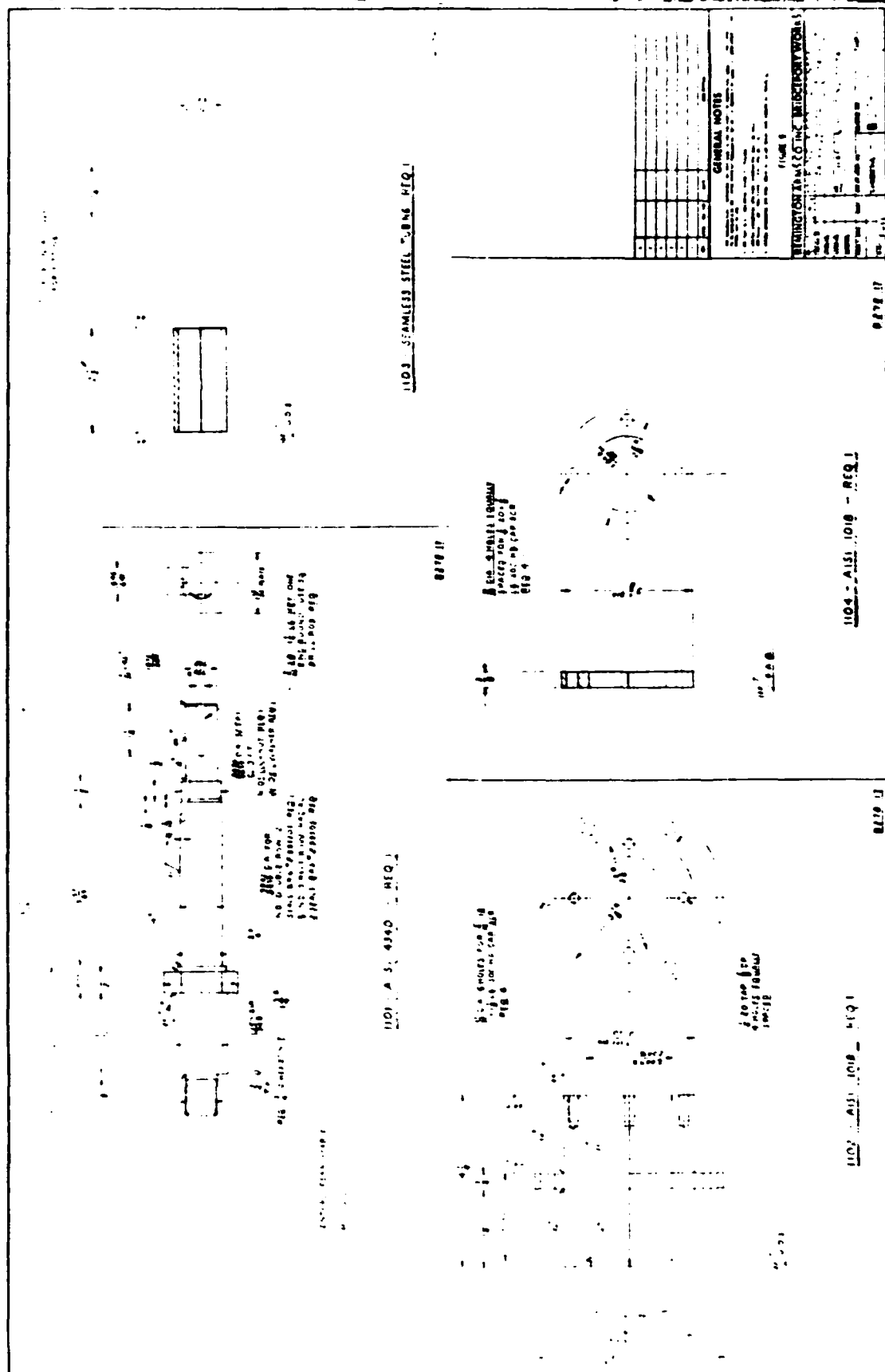
[illegible][illegible]

FIGURE 9



57

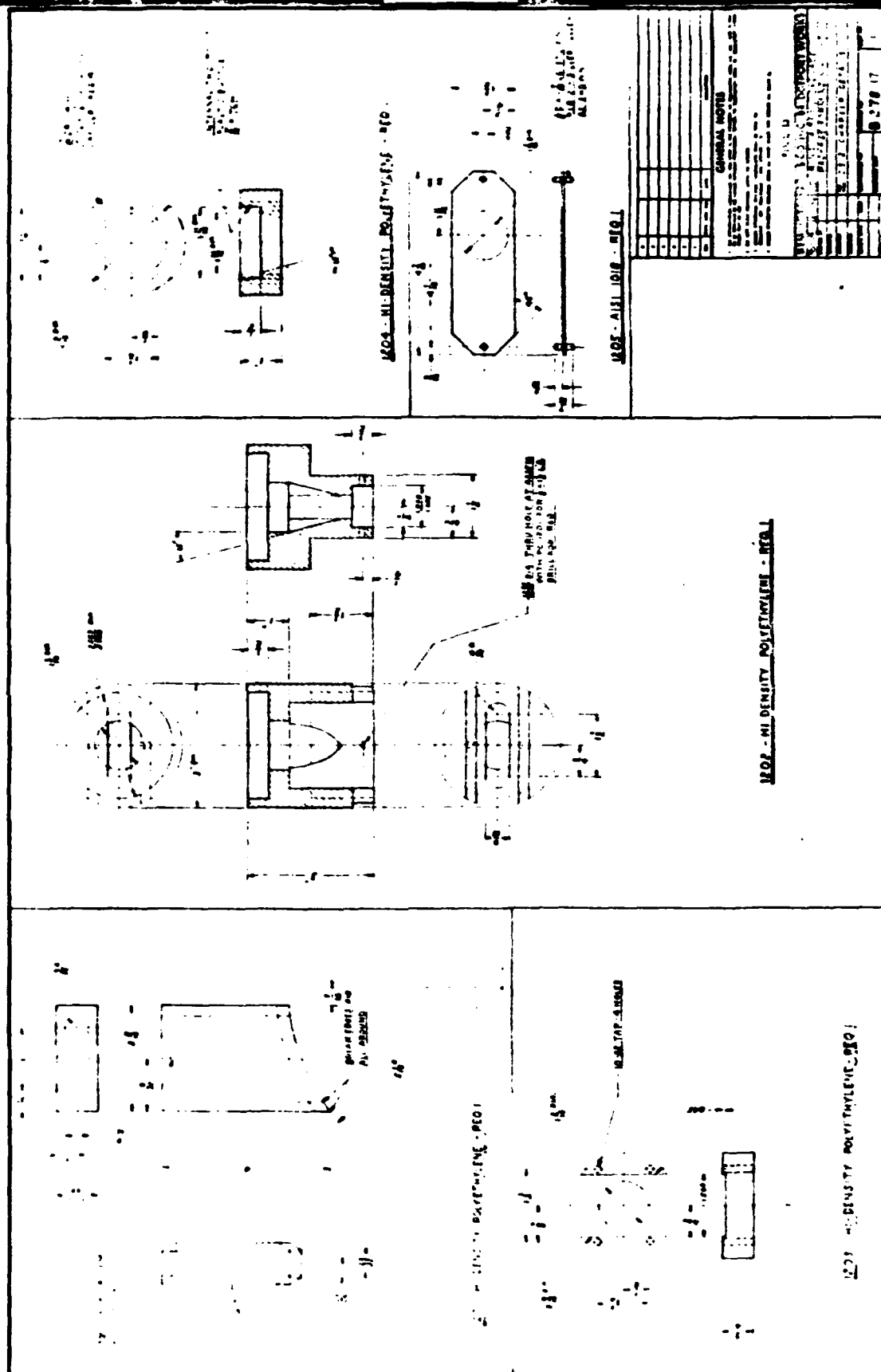
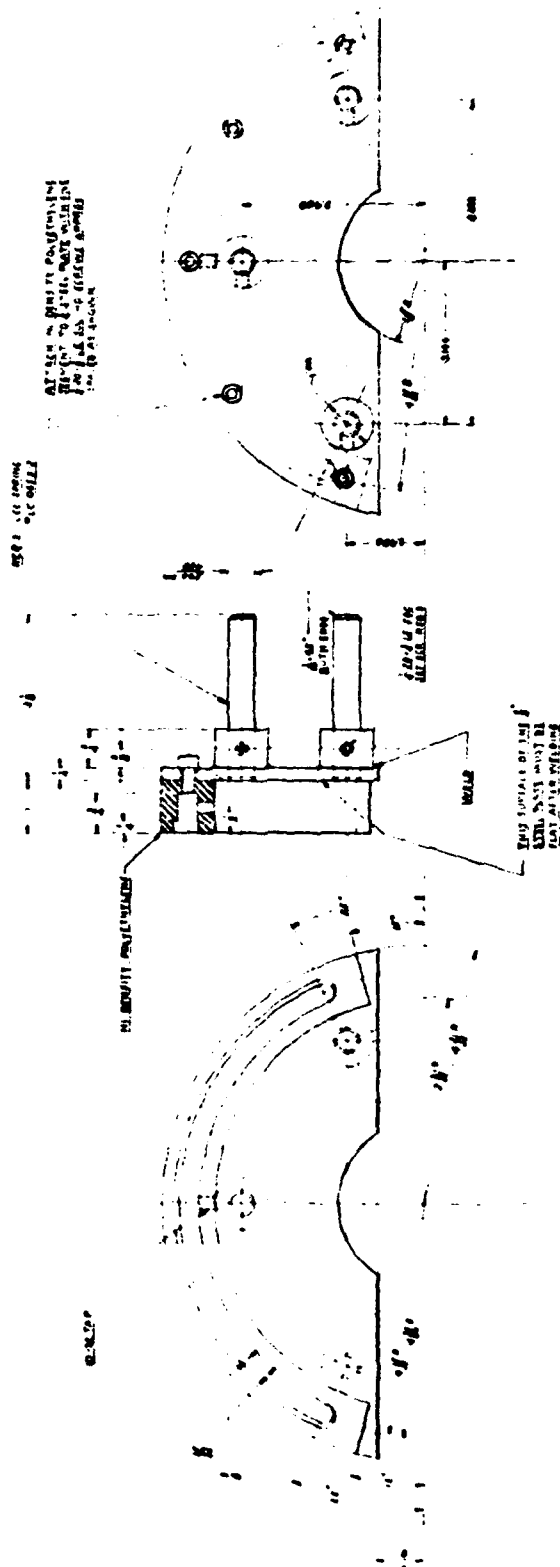


FIGURE 11

Reproduced from
best available copy.



15001 - A131 1018 AND M1 DENSITY POLYETHYLENE - REQ 1

[illegible]

FIGURE 12

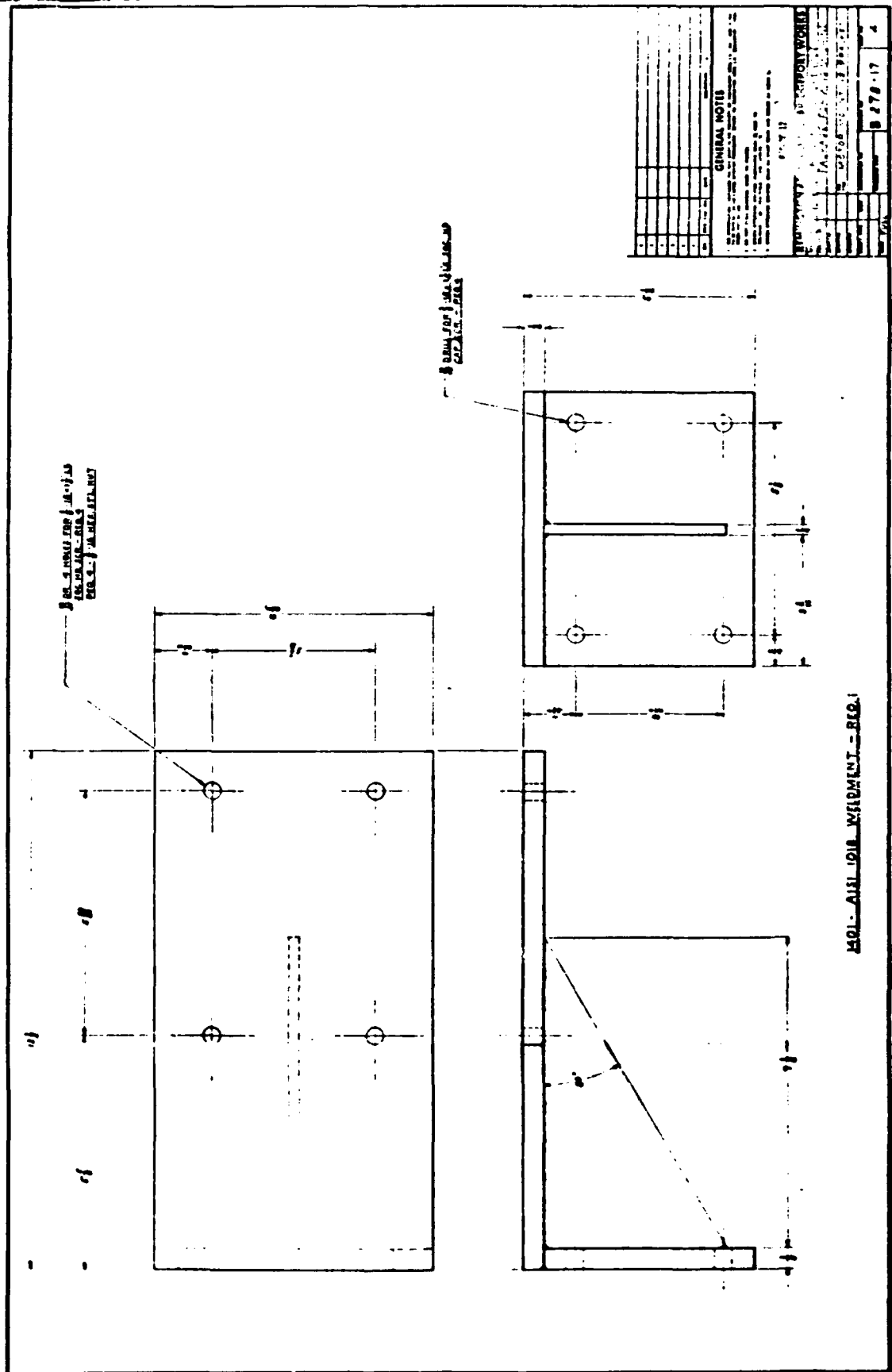
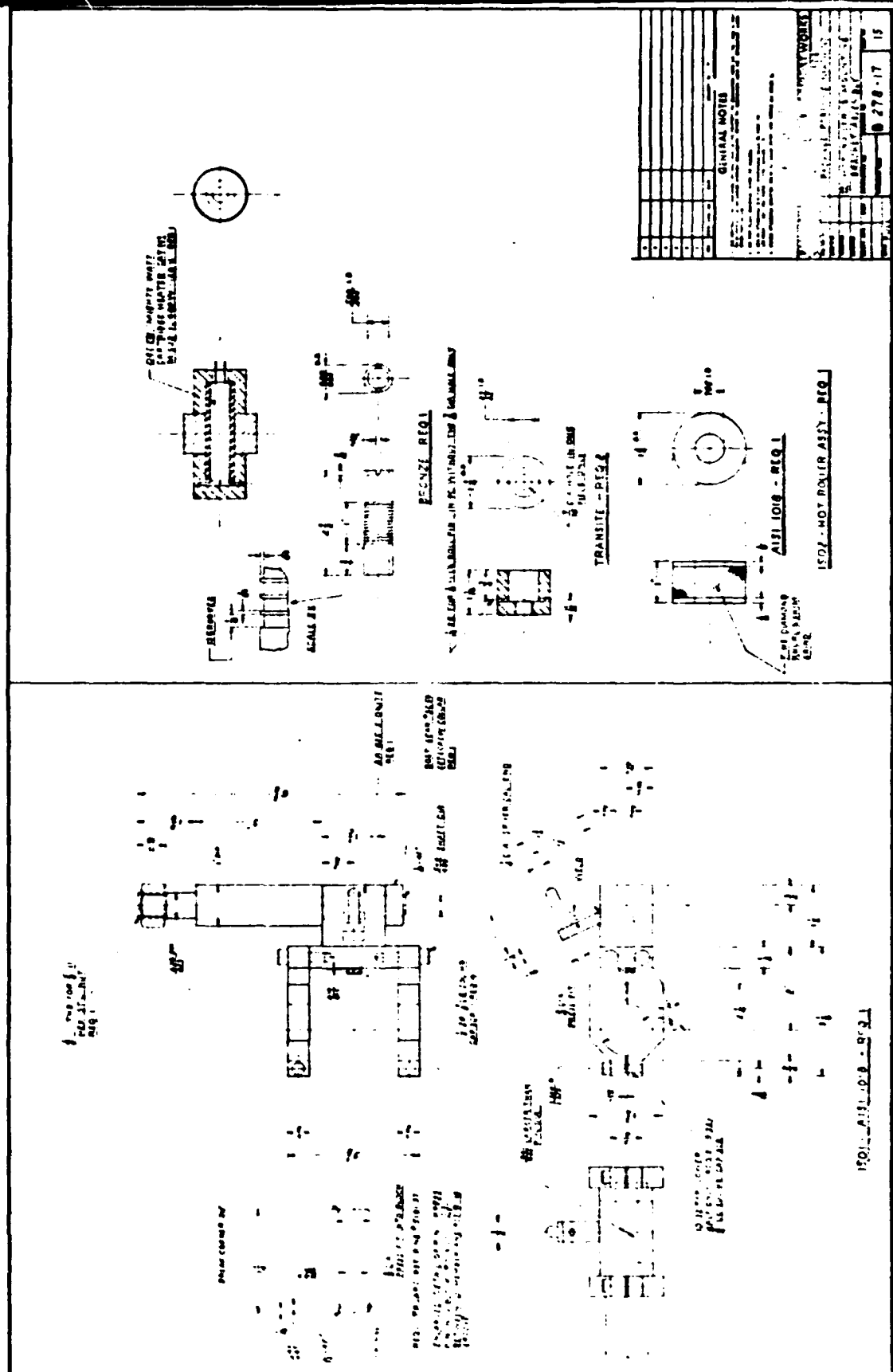


FIGURE 13



Reproduced from
best available copy.

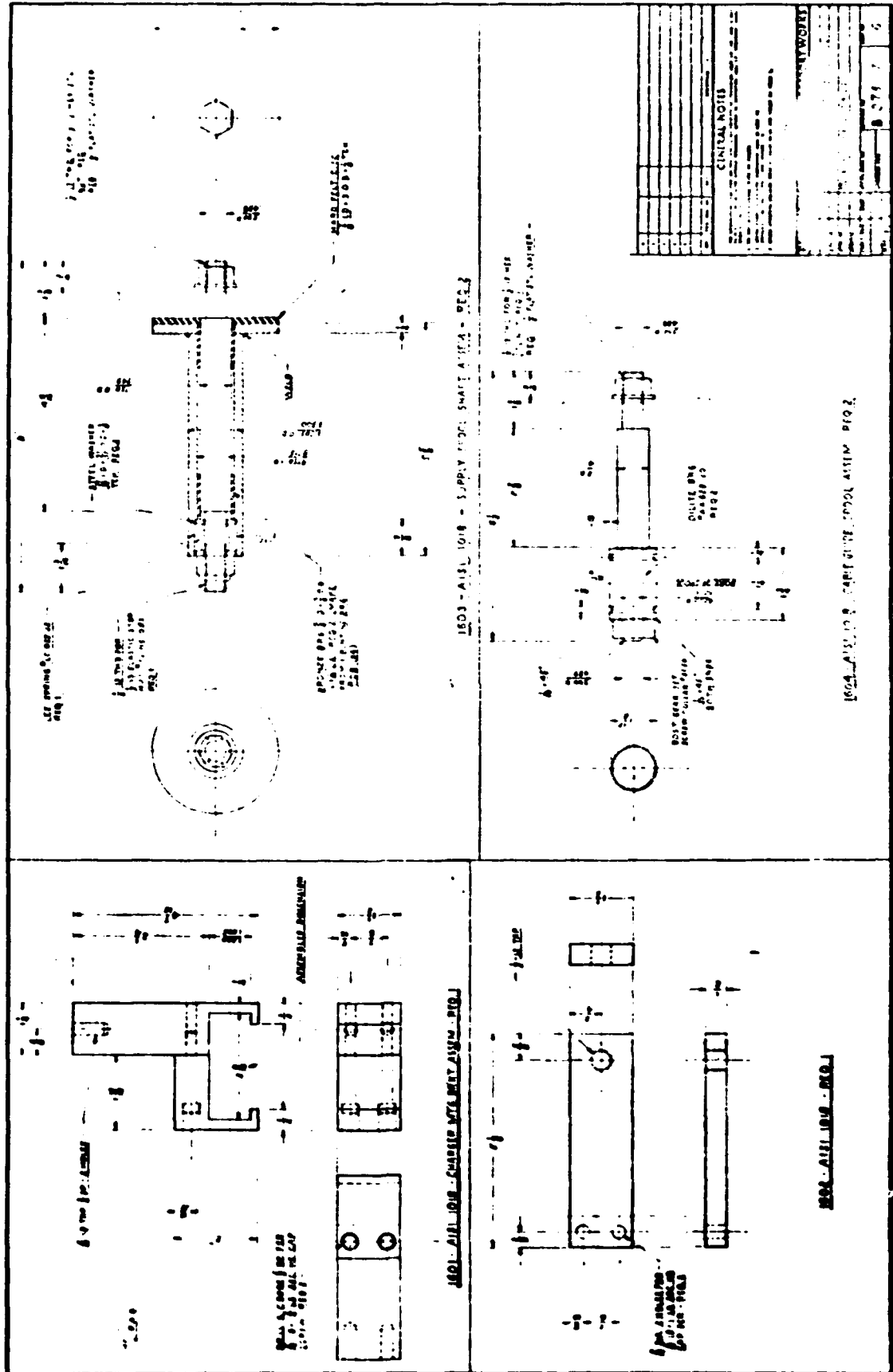
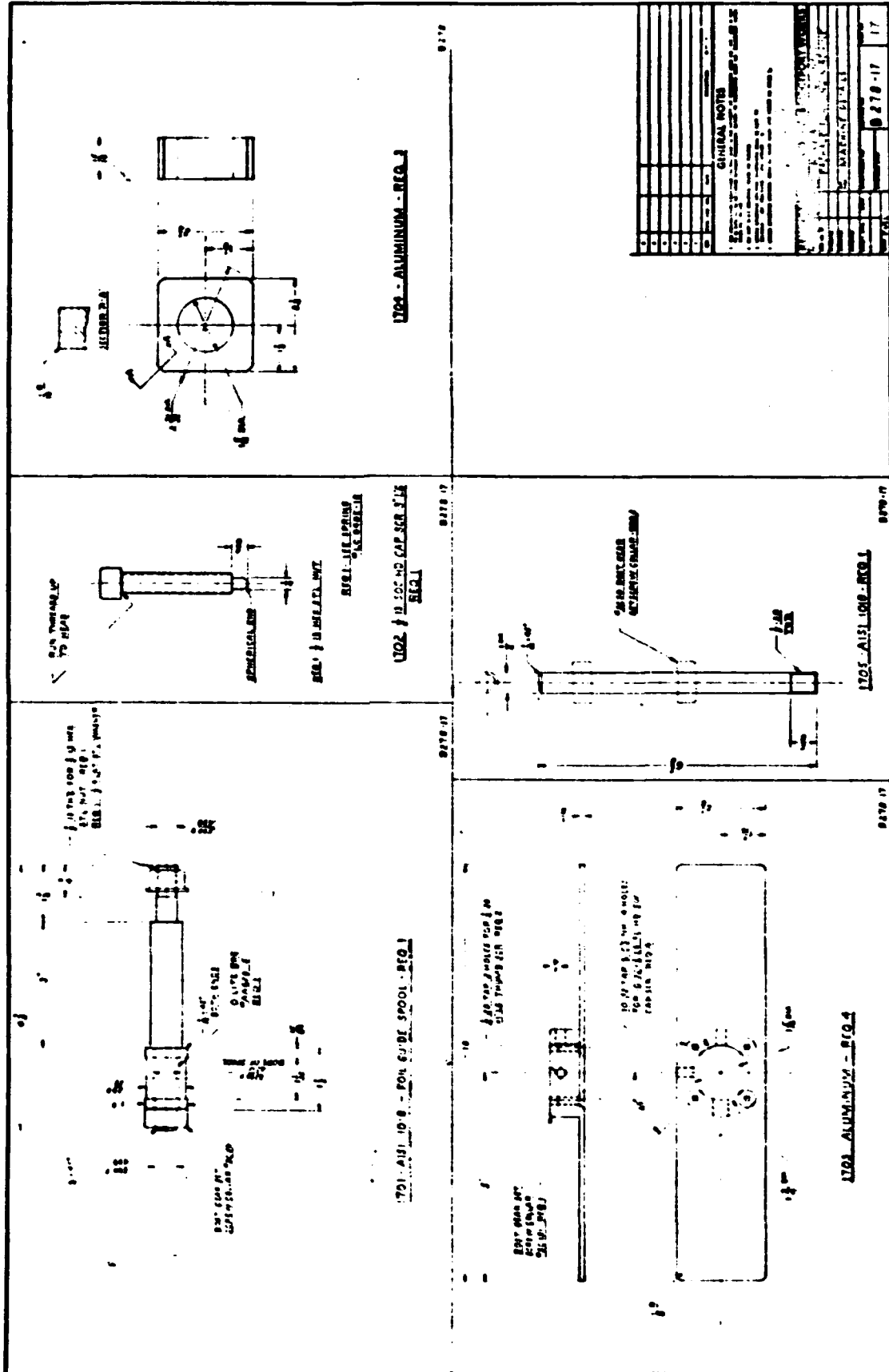


FIGURE 15



Top View Dimensions:

- Overall Width: 10.00
- Overall Height: 10.00
- Internal Width: 8.00
- Internal Height: 8.00
- Radius: R.125
- Distance from Center: 1.50
- Distance from Edge: 0.50
- Distance from Center: 1.00
- Distance from Edge: 0.25
- Distance from Center: 0.75
- Distance from Edge: 0.125
- Distance from Center: 0.50
- Distance from Edge: 0.0625
- Distance from Center: 0.25
- Distance from Edge: 0.03125
- Distance from Center: 0.125
- Distance from Edge: 0.015625
- Distance from Center: 0.0625
- Distance from Edge: 0.0078125
- Distance from Center: 0.03125
- Distance from Edge: 0.00390625
- Distance from Center: 0.015625
- Distance from Edge: 0.001953125
- Distance from Center: 0.0078125
- Distance from Edge: 0.0009765625
- Distance from Center: 0.00390625
- Distance from Edge: 0.00048828125
- Distance from Center: 0.001953125
- Distance from Edge: 0.000244140625
- Distance from Center: 0.0009765625
- Distance from Edge: 0.0001220703125
- Distance from Center: 0.00048828125
- Distance from Edge: 0.000244140625
- Distance from Center: 0.0001220703125
- Distance from Edge: 0.00006103515625
- Distance from Center: 0.000030517578125
- Distance from Edge: 0.0000152587890625
- Distance from Center: 0.00000762939453125
- Distance from Edge: 0.000003814697265625
- Distance from Center: 0.0000019073486328125
- Distance from Edge: 0.00000095367431640625
- Distance from Center: 0.000000476837158203125
- Distance from Edge: 0.0000002384185791015625
- Distance from Center: 0.00000011920928955078125
- Distance from Edge: 0.000000059604644775390625
- Distance from Center: 0.0000000298023223876953125
- Distance from Edge: 0.00000001490116119384765625
- Distance from Center: 0.000000007450580596923828125
- Distance from Edge: 0.0000000037252902984619140625
- Distance from Center: 0.00000000186264514923095703125
- Distance from Edge: 0.000000000931322574615478515625
- Distance from Center: 0.0000000004656612873077392578125
- Distance from Edge: 0.00000000023283064365386962890625
- Distance from Center: 0.000000000116415321826934814453125
- Distance from Edge: 0.0000000000582076609134674072265625
- Distance from Center: 0.00000000002910383045673370361328125
- Distance from Edge: 0.000000000014551915228366851806640625
- Distance from Center: 0.0000000000072759576141834259033203125
- Distance from Edge: 0.00000000000363797880709171295166015625
- Distance from Center: 0.000000000001818989403545856475830078125
- Distance from Edge: 0.0000000000009094947017729282379150390625
- Distance from Center: 0.00000000000045474735088646411895751953125
- Distance from Edge: 0.000000000000227373675443232059478759765625
- Distance from Center: 0.0000000000001136868377216160297393798828125
- Distance from Edge: 0.00000000000005684341886080801486968994140625
- Distance from Center: 0.000000000000028421709430404007434844970703125
- Distance from Edge: 0.0000000000000142108547152020037174224853515625
- Distance from Center: 0.00000000000000710542735760100185871124267578125
- Distance from Edge: 0.000000000000003552713678800500929355621337890625
- Distance from Center: 0.0000000000000017763568394002504646778106689453125
- Distance from Edge: 0.00000000000000088817841970012523233890533447265625
- Distance from Center: 0.000000000000000444089209850062616169452667236328125
- Distance from Edge: 0.0000000000000002220446049250313080847263336181640625
- Distance from Center: 0.00000000000000011102230246251565404236316680908203125
- Distance from Edge: 0.000000000000000055511151231257827021181583404541015625
- Distance from Center: 0.0000000000000000277555756156289135105907917022705078125
- Distance from Edge: 0.00000000000000001387778780781445675529539585113525390625
- Distance from Center: 0.000000000000000006938893903907228377647697925567626953125
- Distance from Edge: 0.0000000000000000034694469519536141888238489627838134765625
- Distance from Center: 0.00000000000000000173472347597680709441192448139190673828125
- Distance from Edge: 0.000000000000000000867361737988403547205962240695953369140625
- Distance from Center: 0.0000000000000000004336808689942017736029811203479766845703125
- Distance from Edge: 0.00000000000000000021684043449710088680149056017398834228515625
- Distance from Center: 0.000000000000000000108420217248550443400745280086994171142578125
- Distance from Edge: 0.0000000000000000000542101086242752217003726400434970855712890625
- Distance from Center: 0.00000000000000000002710505431213761085018632002174854278564453125
- Distance from Edge: 0.000000000000000000013552527156068805425093160010874271392822265625
- Distance from Center: 0.0000000000000000000067762635780344027125465800054371356964111328125
- Distance from Edge: 0.00000000000000000000338813178901720135627329000271856784820556640625
- Distance from Center: 0.000000000000000000001694065894508600678136645001359283924102783203125
- Distance from Edge: 0.0000000000000000000008470329472543003390683225006796419620513916015625
- Distance from Center: 0.00000000000000000000042351647362715016953416125033982098102569580078125
- Distance from Edge: 0.000000000000000000000211758236813575084767080625169910490512847900390625
- Distance from Center: 0.00000000000000000000010587911840678754238354031258495524

Reproduced from
best available copy.

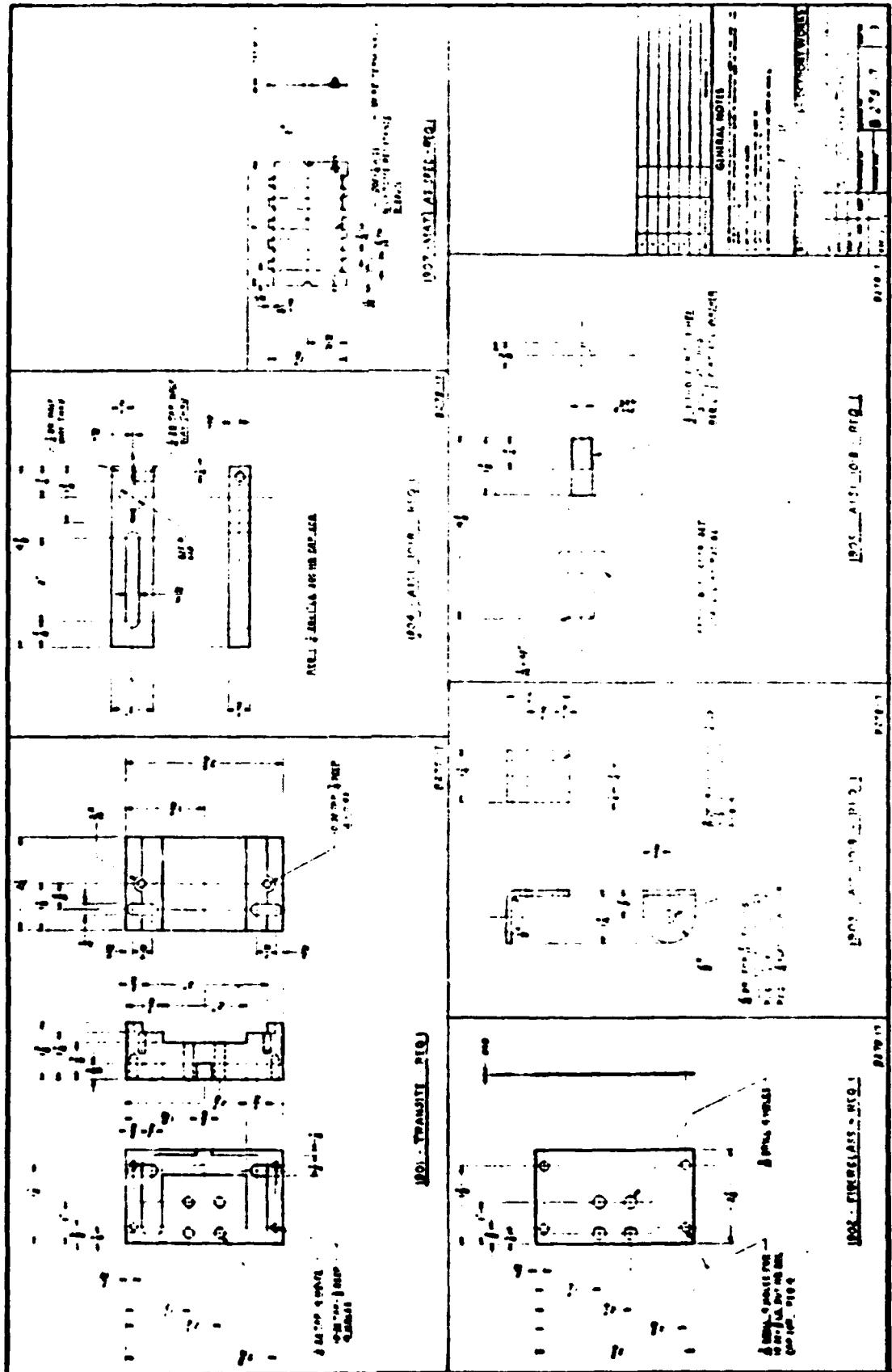


FIGURE 18

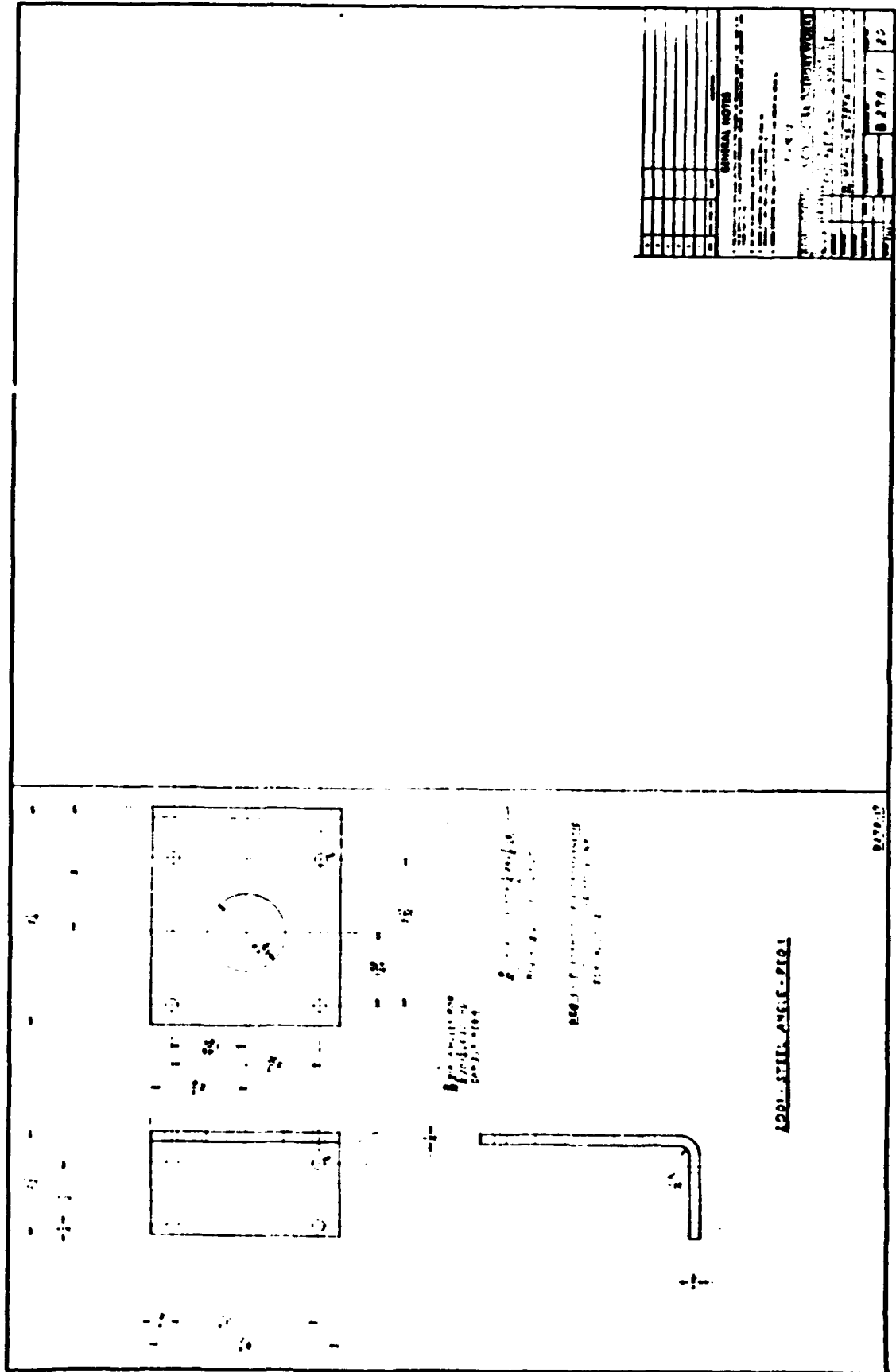


FIGURE 19

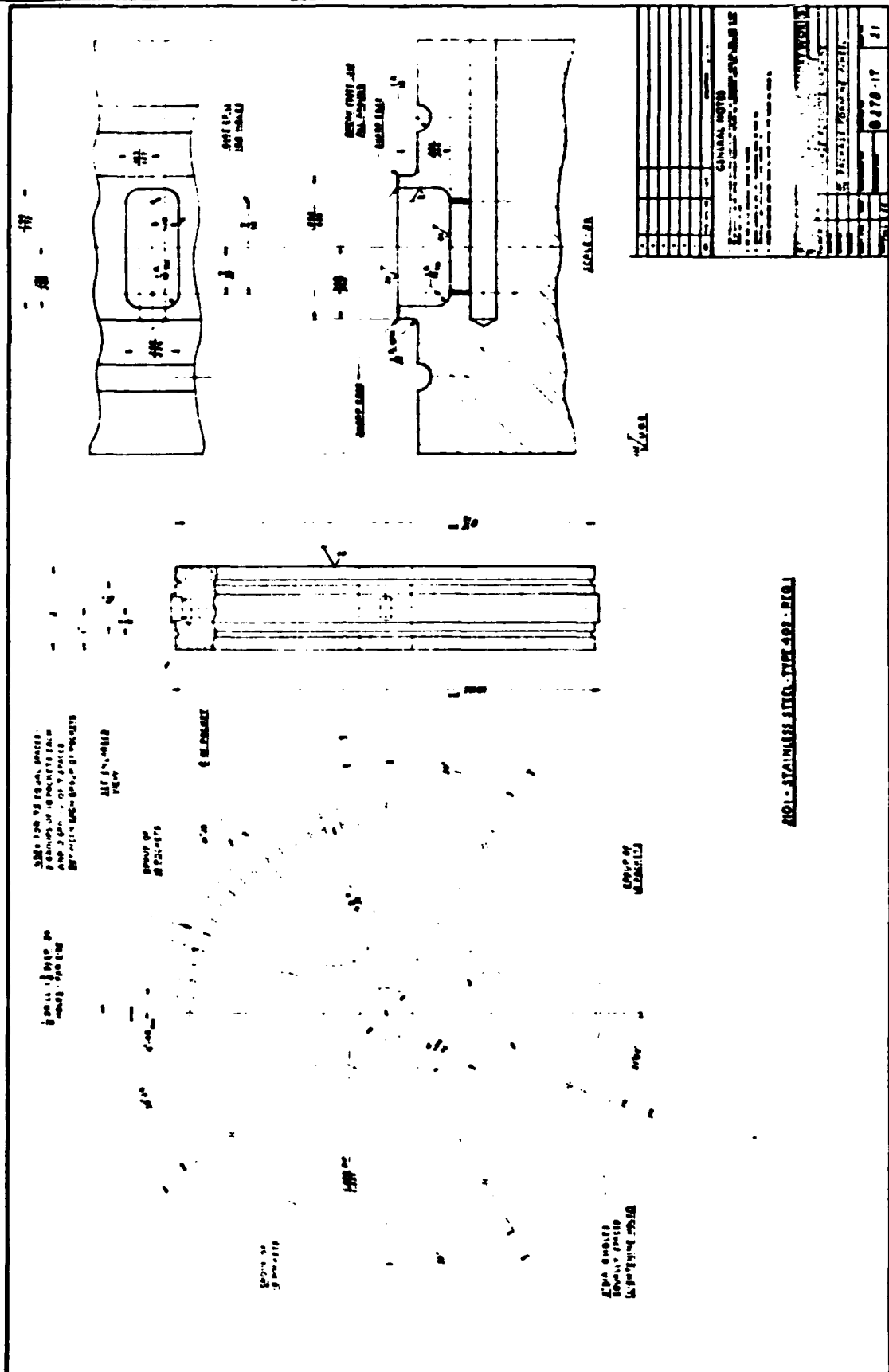


FIGURE 20

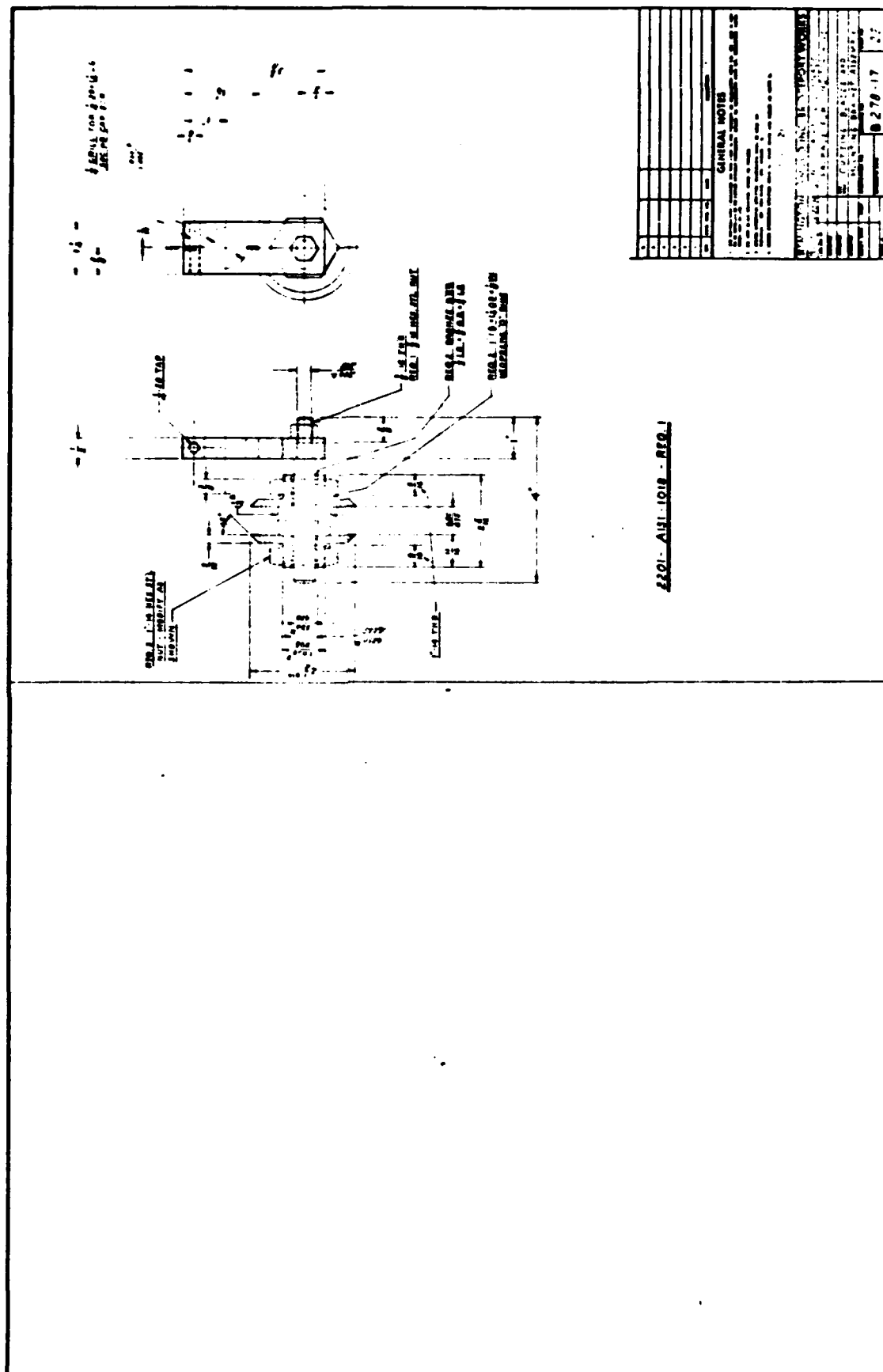


FIGURE 21

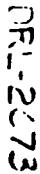
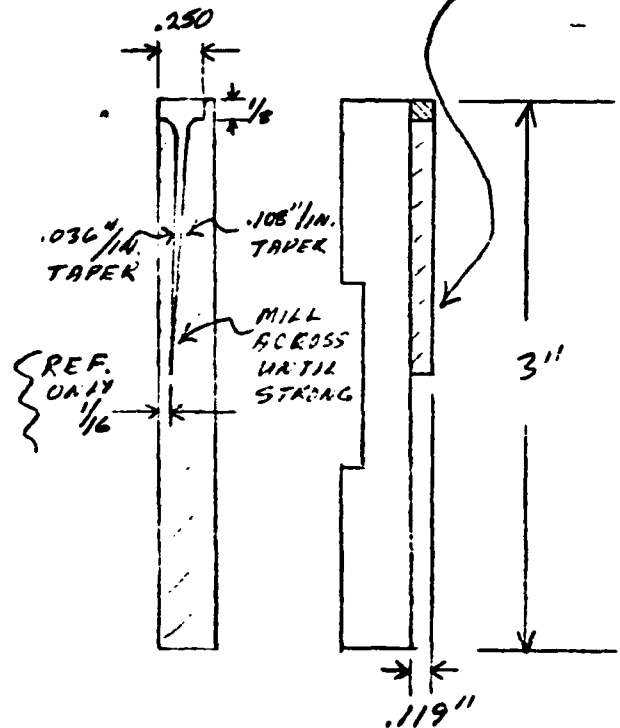
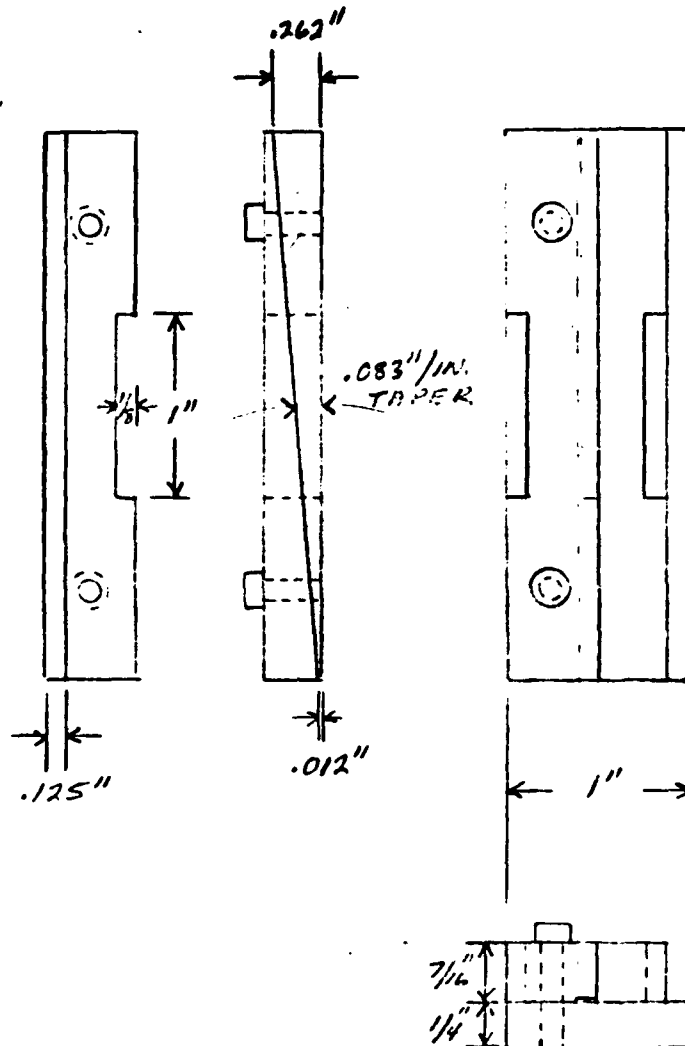


FIGURE 22

81-17078-102

NOTE: SHARP
END ON FOLDER
NOT ESSENTIAL.
MILL ACROSS TO
BLUNT END SHEET



MATERIAL

LOW CARBON GROUND ST.

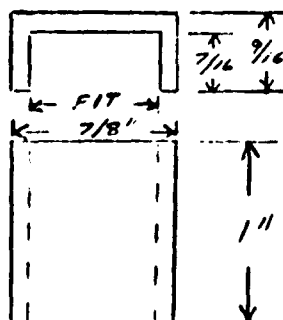
(1) 1/4" x 1" x 3"

(2) 7/16" x 1/2" x 3"

(2) 10-32 ALLEN CAP SCW

HOLDER
CLIP

STEEL



REMINGTON ARMS CO., INC., - BPT., CONN.
RESEARCH & DEVELOPMENT DEPT.

**XM-742 BREAKBAND
TISSUE FOLDER**

DRAWN *[Signature]* APP'D *[Signature]*

DATE 5/1/51

SKRL-5-1074-1

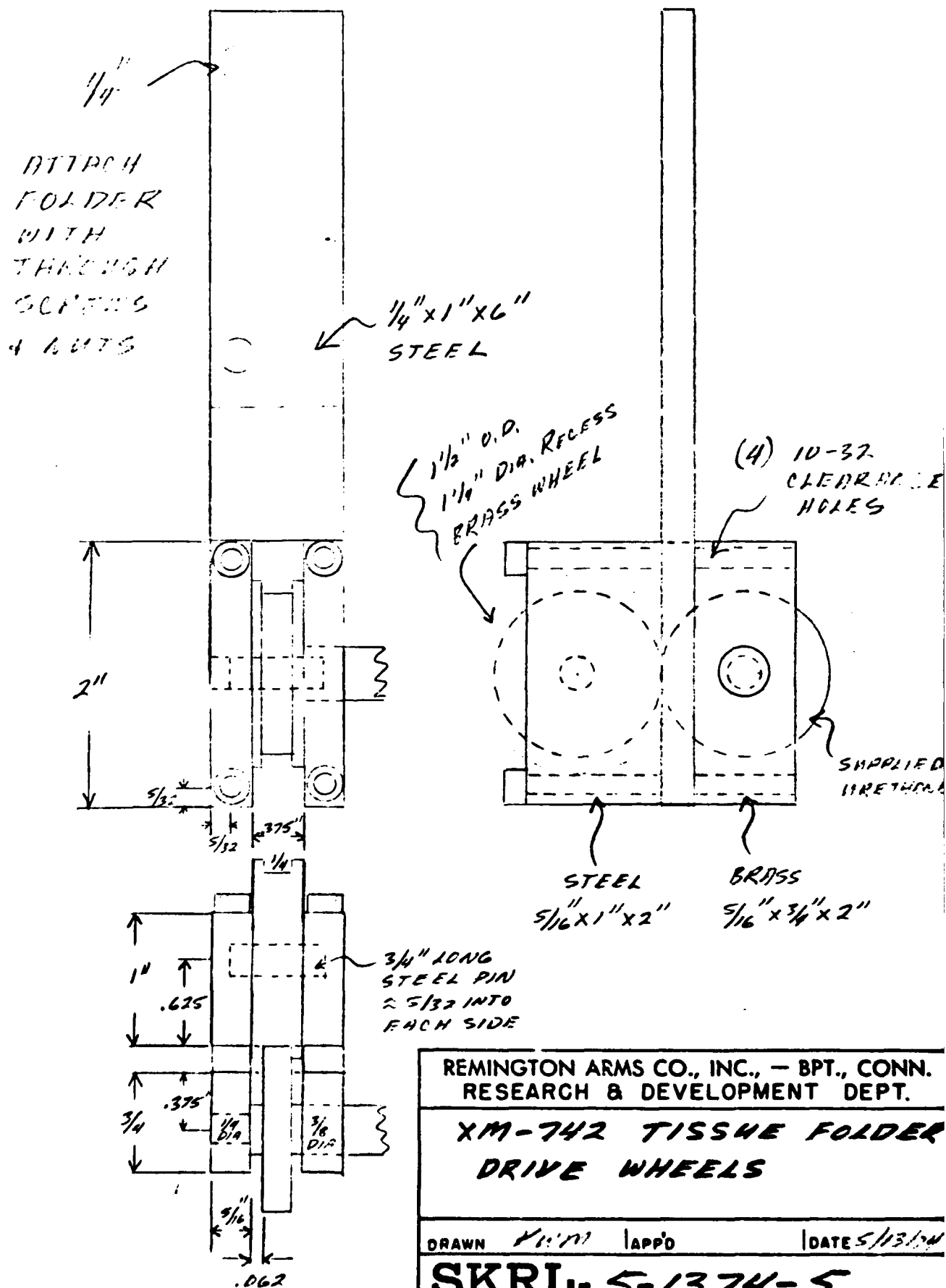
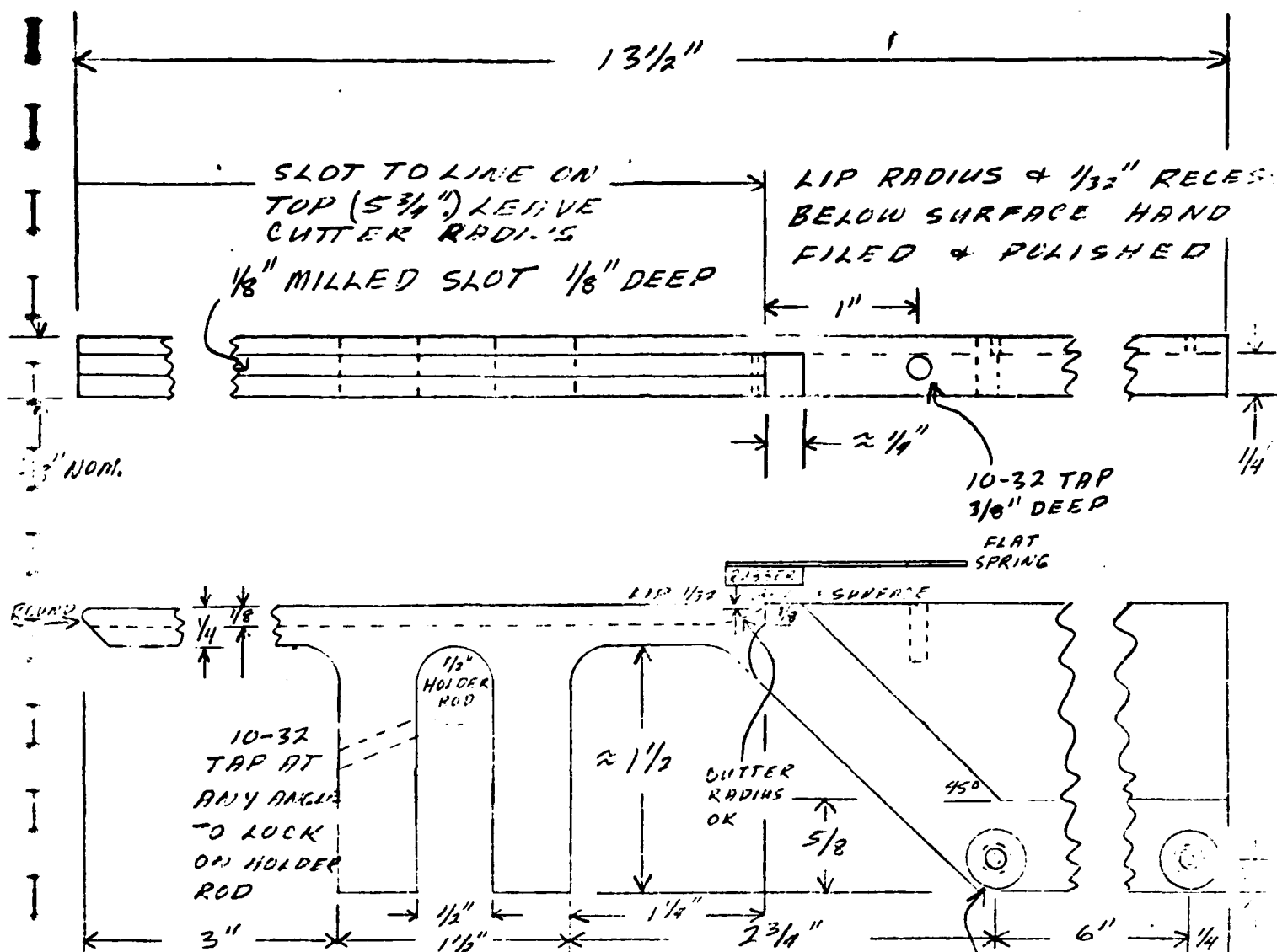


FIGURE 24



ALL LARGE RADII $\frac{1}{2}$ " END WILL

MATERIAL: 304 S.S.

REMOVE ALL SHARP
EDGES, BUFF SHINY
BEFORE ASSEMBLY

81-17078-102

SPOOL IS H.D.
POLYETHYLENE
WITH ANY HARD
1/16" STEEL PIN,
LIGHT PRESS IN
STRESSLESS STEP

REMINGTON ARMS CO., INC., - BPT., CONN.
RESEARCH & DEVELOPMENT DEPT.

X17 742, X17 743
TISSUE IMPREGNATOR

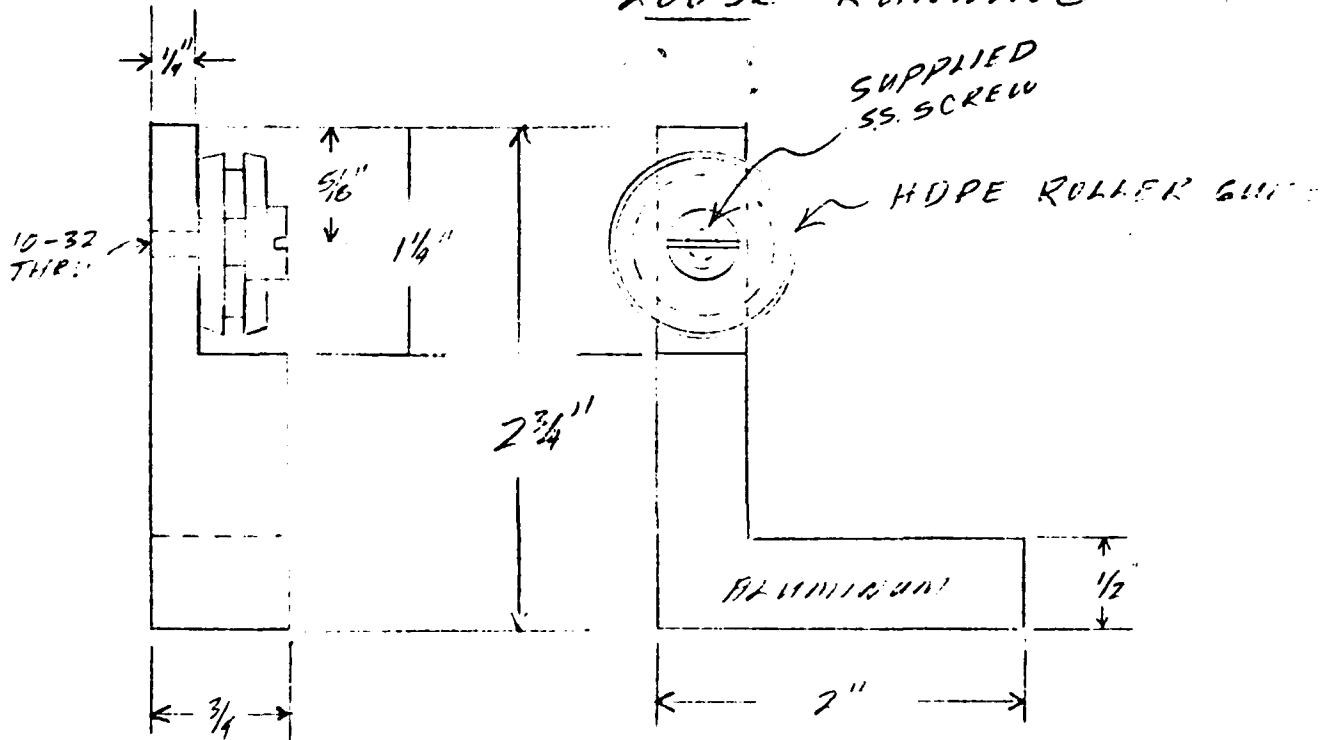
DRAWN	APP'D	DATE
-------	-------	------

SKRL-5-2274-1

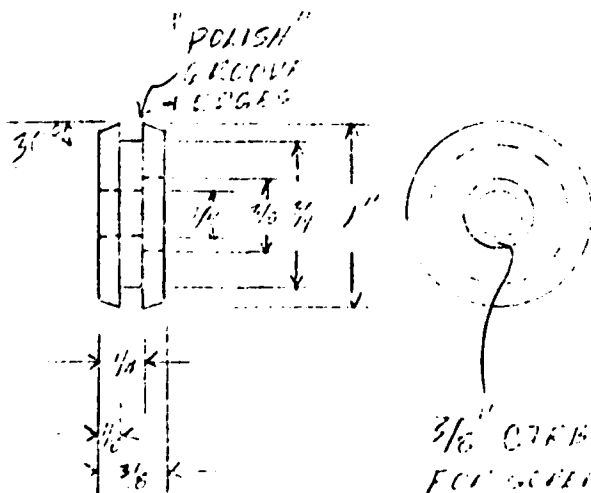
R. D. 9791

FIGURE 25

FIT ROLLER FOR
FREE BUT NOT
LOOSE RUNNING



S.S. SHOULDER
SCREW SUPPLIED



81-17079-102

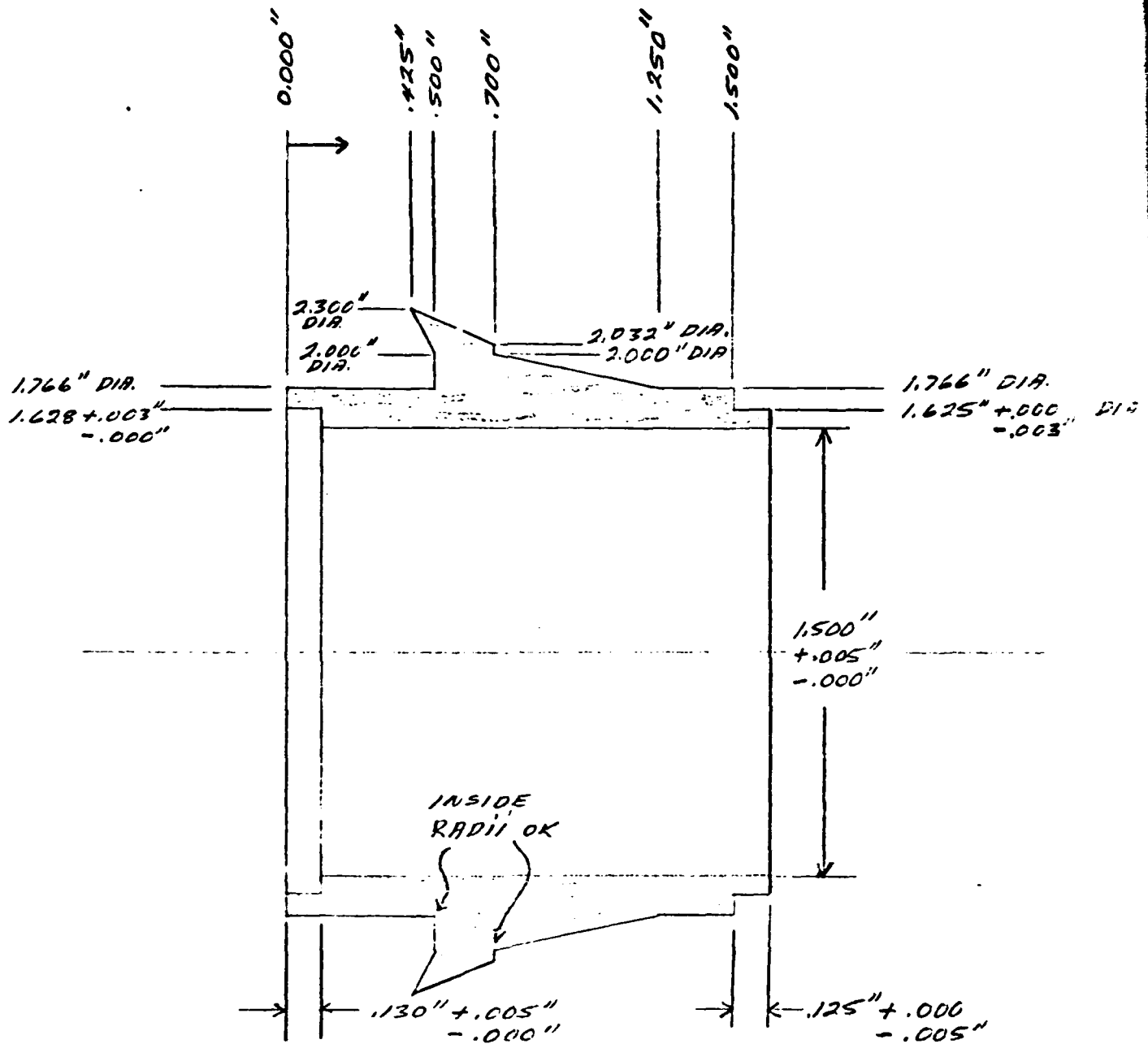
REMINGTON ARMS CO., INC., - BPT., COND
RESEARCH & DEVELOPMENT DEPT.

XM-743 LANDING
GUIDE ROLLER

DRAWN *[Signature]* APP'D *[Signature]* DATE

SKRL- 9-1374-1

FIGURE 26



{ ALL TOLERANCES
± .003" UNLESS
OTHERWISE NOTED.

NEED MULTIPLES
OF SEVEN (7)
A PRODUCT UNIT

REMINGTON ARMS CO., INC., - BPT., CONN. RESEARCH & DEVELOPMENT DEPT.		
REVISED XM-742,3 BANDING MANDREL (RE: SKRL 5-2874-1)		
DRAWN	APP'D	DATE
SKRL- 7-1474-1		

Reproduced from
best available copy.

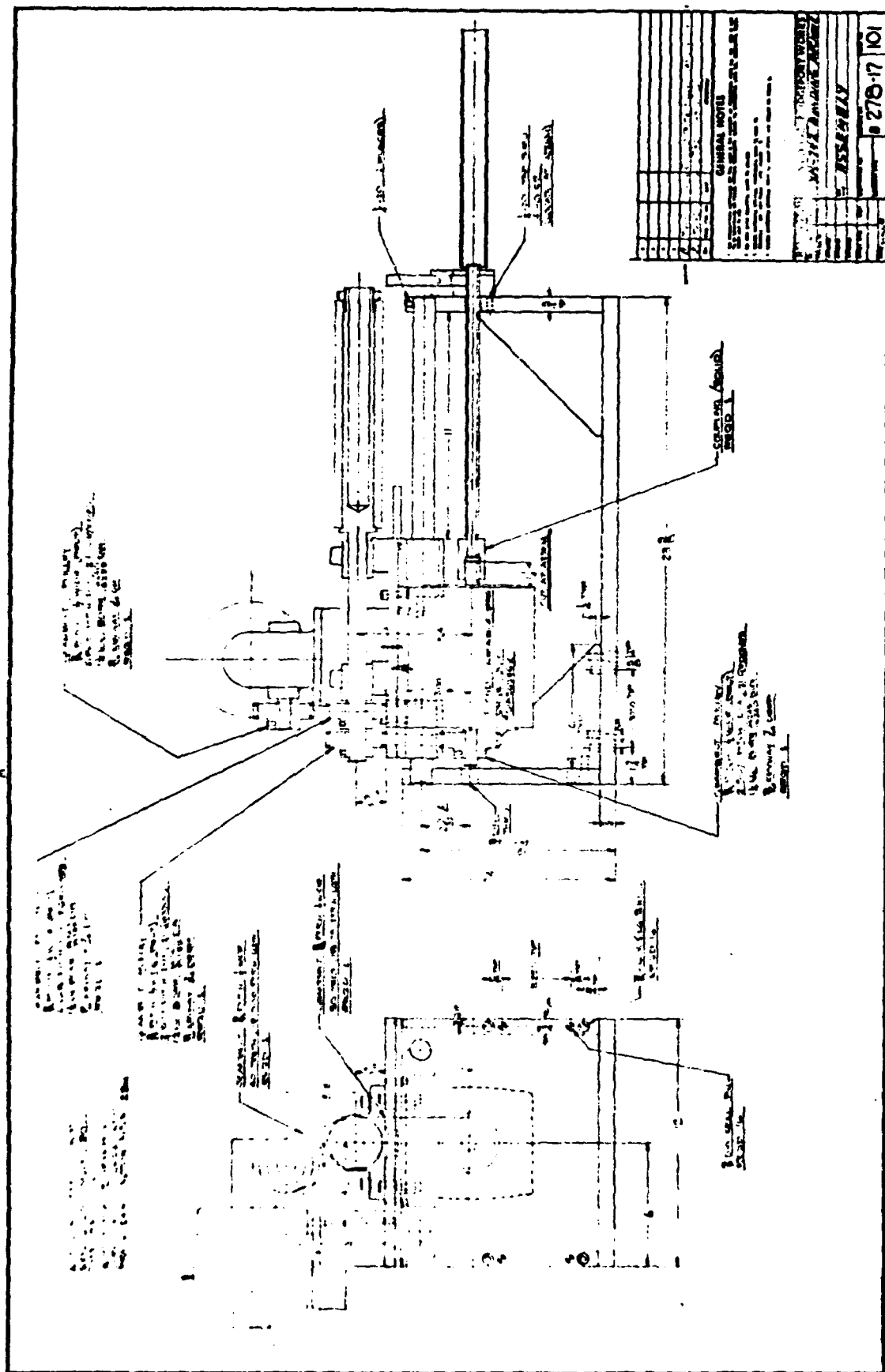


FIGURE 28

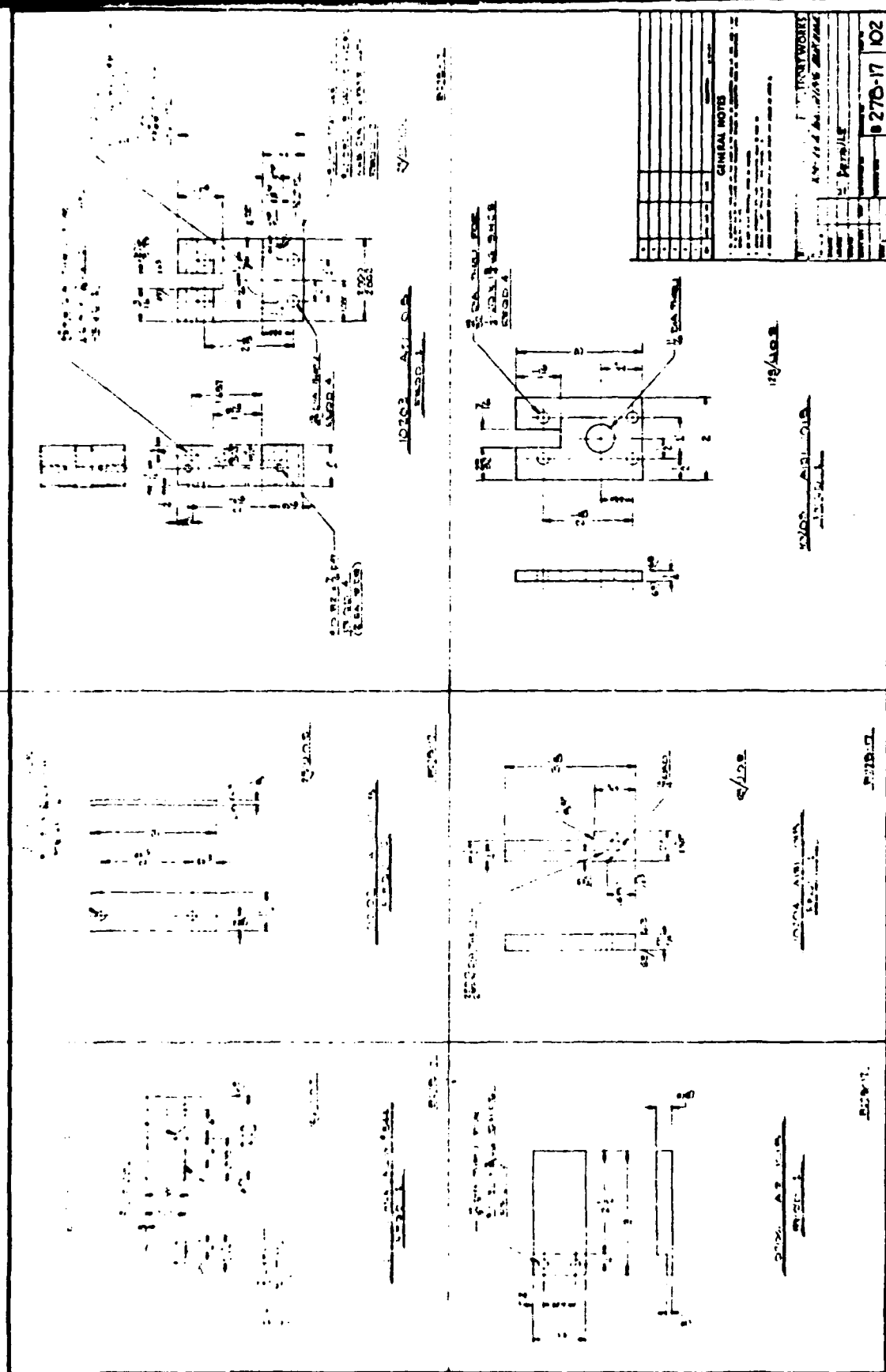


FIGURE 29

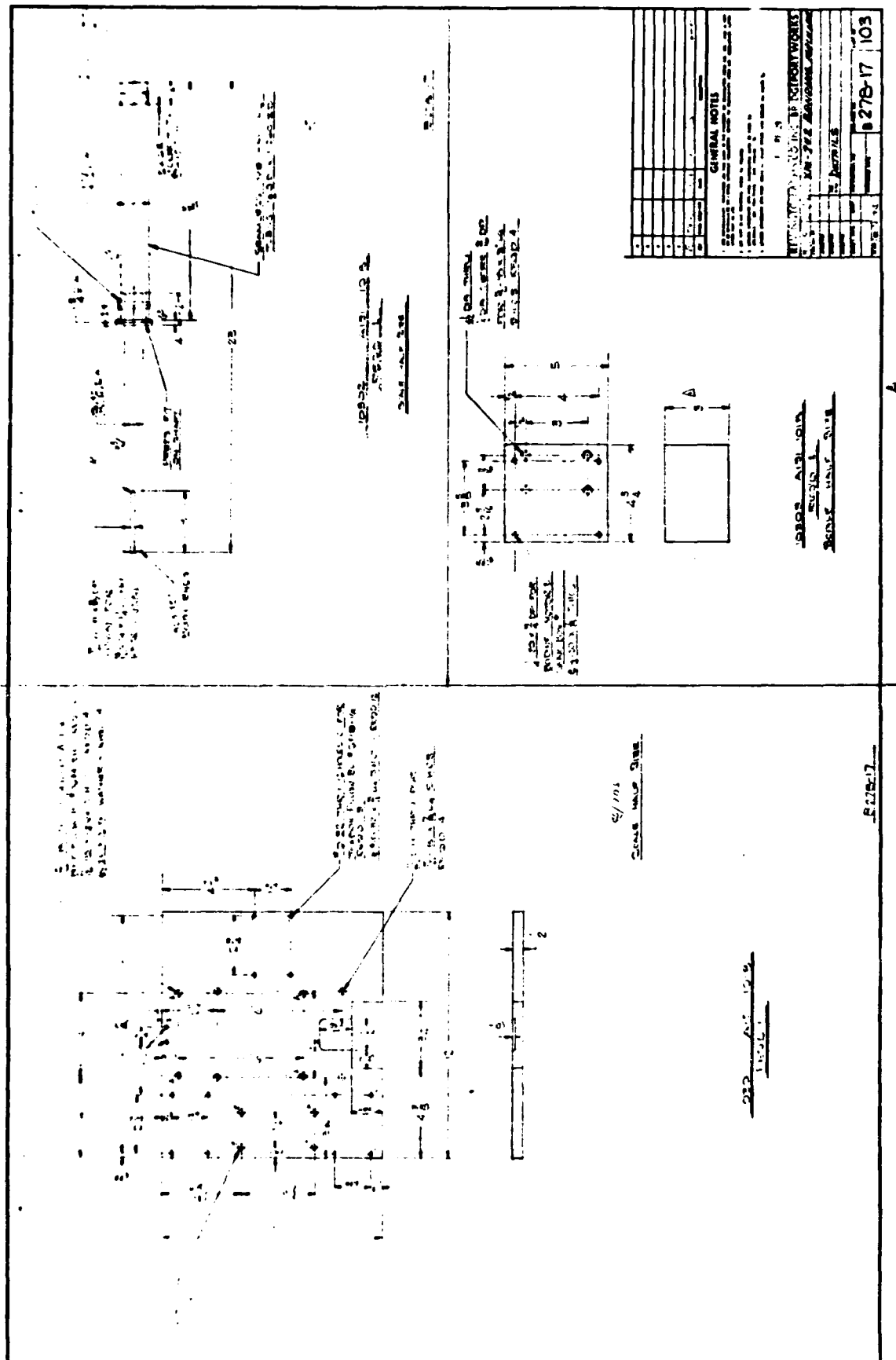


FIGURE 30

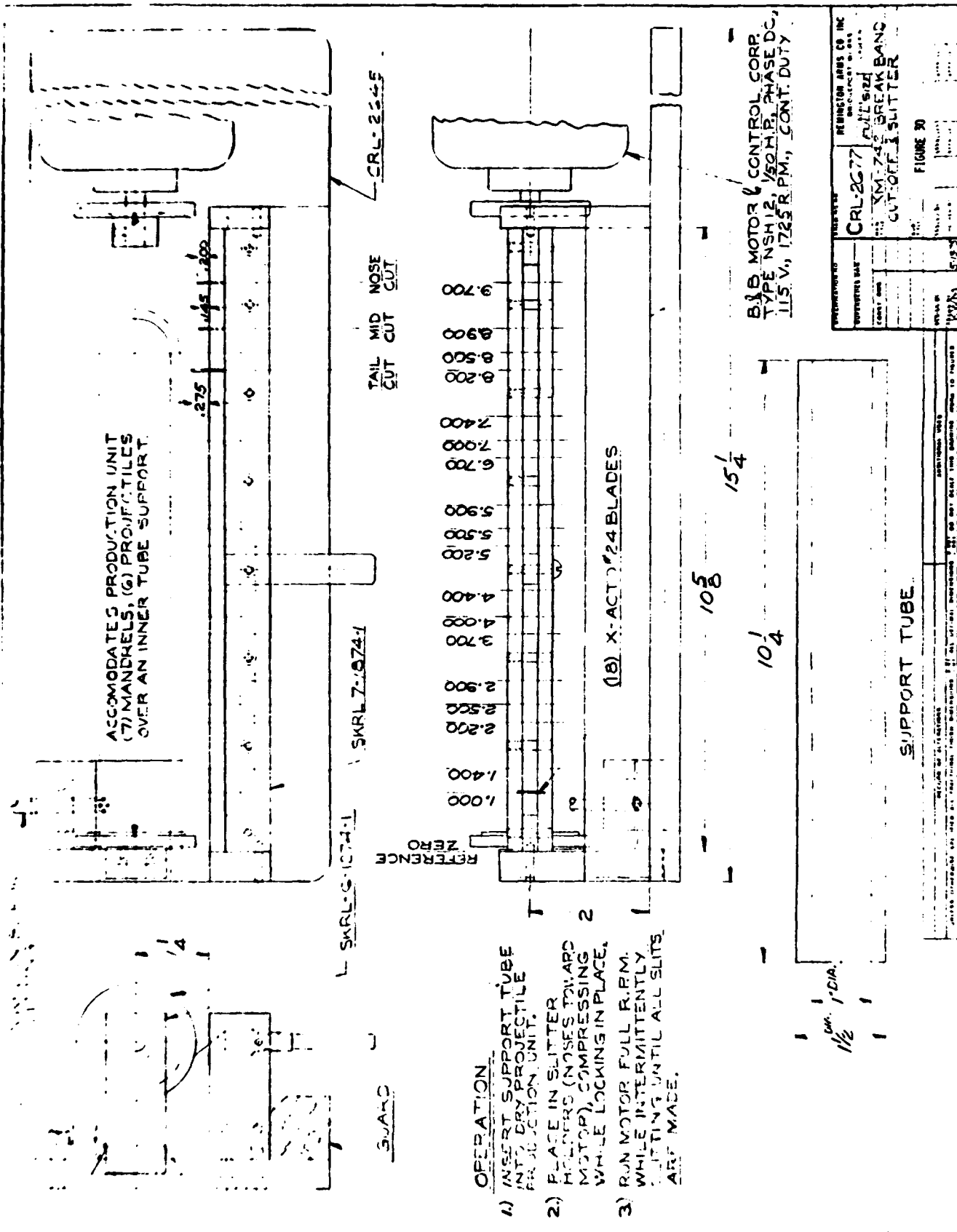


FIGURE 31

STING RAG TEST MATRIX

- 12 PROJECTILES EACH CONDITION: SIX PRODUCTION BODIES
(240 TOTAL IN TEST) SIX PRODUCTION BODIES POST-CURED ONE HOUR @ 300F
(DENOTED BY LETTER "C")
- ALL BANDINGS CONSOLIDATED AFTER WRAPPING ONLY ON NOSE AND TAIL, NOT CAVITIES.
- ALL PROJECTILES CROSSLINKED 3 MIN. @ 300F FROM ROOM TEMPERATURE. (12 at a time)

Wrap Sequence	Condition Number	Catalyst	Wrap Rate	Pre-Wrap	Wrap Tension	Band Dry	General Test Results
1,2	1	NO	17	NO	NORMAL	OVERNITE	_____
3,4	2	NO	17	NO	NORMAL	FOUR HOURS	_____
5,6	3	NO	17	NO	NORMAL	1 HR. @ 125F	_____
7,8	4	NO	20	NO	NORMAL	OVERNITE	_____
9,10	5	NO	20	NO	NORMAL	FOUR HOURS	_____
11,12	6	NO	20	NO	NORMAL	1 HR. @ 125F	_____
33,34	7	YES	17	NO	TIGHT ¹	OVERNITE	_____
25,26	8	YES	20	NO	TIGHT	OVERNITE	_____
35,36	9	YES	17	NO	NORMAL	OVERNITE	_____
15,16	10	YES	17	NO	NORMAL	FOUR HOURS	_____
17,18	11	YES	17	NO	NORMAL	1 HR. @ 125F	_____
27,28	12	YES	20	NO	NORMAL	OVERNITE	_____
13,14	13	YES	20	NO	NORMAL	FOUR HOURS	_____
21,22	14	YES	20	NO	NORMAL	1 HR. @ 125F	_____
37,38	15	YES	17	ALUM. ²	NORMAL	OVERNITE	_____
19,20	16	YES	17	ALUM.	NORMAL	1 HR. @ 125F	_____
29,30	17	YES	20	ALUM.	NORMAL	OVERNITE	_____
23,24	18	YES	20	ALUM.	NORMAL	1 HR. @ 125F	_____
39,40	19	YES	17	FOAM ³	NORMAL	OVERNITE	_____
31,32	20	YES	20	FOAM	NORMAL	OVERNITE	_____

1 - "Tight" means guide roller on banding machine is locked so band must slide.

2 - "Alum." is .00025 X 1 X 6 in. aluminum foil wrapped over cavities and cement tracked.

3 - "Foam" is 1/16 X 21/32 X 7/8 in. polyethylene foam over cavities, held with 1/2" tape

[illegible]

FIGURE 1	FIGURE 2
<p>FIGURE 1</p> <p>FIGURE 2</p>	<p>FIGURE 1</p> <p>FIGURE 2</p>